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Volume XXXII July-September 1988

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A MONOGRAPH OF THE GENUS UNGUICULARIOPSIS (LEOTIACEAE, ENCOELIOIDEAE)

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ABSTRACT

The genus *Unguiculariopsis* was coined for a single species, *U. ilicincola*. The generic name has been accepted by only a few mycologists and, until recently, only three additional species had been referred to the genus. The species accepted here were placed in eighteen genera of five families belonging to three different orders. Moreover, the same species has been put in many genera by different workers. The genus was poorly known and the generic concept was ambiguous.

This monograph aims at bringing closely related fungi together and at giving a clear generic concept and specific delimitation. According to the current International Code of Botanical Nomenclature, *Unguiculariopsis* is the correct generic name for a small group of fungicolous, inoperculate Discomycetes. Fifteen species are recognized, including four new species, *U. acerina*, *U. adirondacensis*, *U. godroniicola*, and *U. rehmii*; a new subspecies, *U. robergei* subspecies *coelomyceticola*; and eight new combinations, *U. australiensis*, *U. dimorpha*, *U. hamatopilosa*, *U. livida*, *U. parasitica*, *U. ravenelii* subsp. *hamata*, *U. robergei*, and *U. thallophila*. A dichotomous key to the species of *Unguiculariopsis* is provided. The taxonomic status of the genus is discussed. The genus is removed from the Hyaloscyphaceae, to which it was traditionally assigned, and transferred to the Encoelioideae of the Leotiaceae on the basis of apothecial anatomy. The host fungi are mainly ascomycetes, and possibly deuteromycetes, as well as basidiomycetes and ascomycetous lichens. The fungus-fungus interaction, host specificity, and world distribution of the genus are demonstrated. A new coelomycete genus, *Deltosperma*, is established to accommodate the anamorphs of three *Unguiculariopsis* species.

Lachnum aconiti is also treated as a new combination.

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INTRODUCTION

The genus *Unguiculariopsis* comprises a small group of inoperculate Discomycetes. They always occur on, or are associated with, other fungi, including various ascomycetes, deuteromycetes, and ascomycetous lichens. The apothecia of this genus are small, cupulate to discoid, of brownish, vinaceous, yellowish, or rosy tint in the hymenium, and of dirty white, light vinaceous to greyish brown color on the receptacle. The outer surface appears furfuraceous because of the presence of short, characteristic hairs. Although only a limited number of specimens have been collected since 1844, species of this genus are distributed worldwide.

Unguiculariopsis was coined for a single species, *U. ilicincola* (Rehm, 1909). The genus was poorly known and the generic concept was ambiguous. For decades, only three species were transferred to the genus (Korf, 1971; Zhuang, 1987), and the generic name has only been accepted by a few authors (Korf, 1971, 1973; Raschle, 1977; Baral & Krieglsteiner, 1985; Spooner, 1987). Its species have been placed in *Cenangium*, *Dermatea*, *Encoelia*, *Encoeliella*, *Hyalopeziza*, *Lachnella*, *Lachnellula*, *Midotis*, *Mollisia*, *Mollisiella*, *Peziza*, *Pithyella*, *Pseudohelotium*, *Pyrenopeziza*, *Skyttea*, *Trochila*, and *Unguiculella*. Moreover, single species have been placed in many genera by different authors.

Unguiculariopsis Rehm is a valid generic name according to the current International Code of Botanical Nomenclature (Voss et al., 1983).

This monograph aims at bringing the species of *Unguiculariopsis* together and at giving a clear generic concept and specific delimitation. Sixteen species are accepted in this genus. Five new species and a new subspecies are described, and eight new combinations are made. A new genus, *Deltosperma*, has been established to accommodate the anamorphs of three species of *Unguiculariopsis*.

MATERIALS AND METHODS

Since the species of *Unguiculariopsis* are very rare, the materials used in this study are mostly dried herbarium specimens except for a few collections from New York State, from France, and from Jamaica. In order to locate taxa and specimens of *Unguiculariopsis* that have been confused with other genera, a careful literature search was carried out. The descriptions of many taxa of the genera in which *Unguiculariopsis* species had been placed were read. The fungicolous and lichenicolous species included in *Enumeratio Systematica Fungorum* (Oudemans, 1919) and in *Die Flechtenparasiten* (Keissler, 1930) were reviewed. A lot of small, hairy and fungus-inhabiting discomycetes were selected, and specimens examined. A large number of specimens of the host fungi have also been secured and examined to see if the relatively inconspicuous *Unguiculariopsis* may have been inadvertently collected at the same time.

Traditional methods of anatomical study were used. The apothecium was wetted with a drop of 95% ethanol and transferred immediately into water. When the apothecium was thoroughly rehydrated, it was embedded in a drop of 50% aqueous mucilage and sectioned on a freezing microtome at 15-20 µm. Sections through the middle of the apothecia were mounted in cotton blue lactic acid (0.05 g soluble blue 706 Hopkins & Williams Revector, 30 ml lactic acid), or in Melzer's reagent (0.5 g iodine, 1.5 g potassium iodide, 20 g chloral hydrate, 20 ml distilled water) with 10 % aqueous KOH solution pretreatment. Squash mounts were made in cotton blue to see the shapes of hairs, of asci, and of paraphyses. A dry apothecium of one species was put on a stub, coated with gold-palladium and observed in an ARM-1000A scanning electron microscope (SEM). The SEM image showed the surface morphology of the apothecium and of hairs. The nuclear number of ascospores was observed in Belling's Iron-acetocarmine solution (1 g carmine, 90 ml glacial acetic acid, a few drops of an aqueous solution of ferric acetate, 110 ml distilled water).

Each species described was based on the morphology of all specimens examined. Terms used in descriptions followed Korf's definitions (Korf, 1952, 1973). All drawings were done with the aid of a drawing tube. Nomenclatural problems were solved according to the International Code of Botanical Nomenclature (Voss, et al., 1983). The abbreviations of references are based on *Botanico - Periodicum - Huntianum* (Lawrence, et al., 1968). The abbreviations of herbaria follow *Index Herbariorum* (Holmgren et al., 1981).

HISTORY OF TAXONOMY AND NOMENCLATURE OF *UNGUICULARIOPSIS*

The genus *Unguiculariopsis* was established for a single species, *U. ilicincola* (Berk. & Br.) Rehm (Rehm, 1909), originally assigned to *Peziza*. At the time Rehm created the generic name, instead of examining and describing the real *Peziza ilicincola* Berk. & Br. (Berkeley and Broome, 1861) which is on *Myriangium,* he described, in detail, his own Ascomycete Exsiccati #1831, a closely related fungus which grows on *Cucurbitaria berberidis* (Pers.) Gray. His material is treated as a new species, *U. rehmii* Zhuang & Korf, in this paper. Under the Sydney revision of the International Code of Botanical Nomenclature (ICBN), the type of the generic name is the type specimen of the named type species (Voss, et al., 1983). Even though what Rehm described was not *Peziza ilicincola,* he used that name as the only species of the genus; we must accept the type specimen of *Peziza ilicincola* as representing the type of generic name *Unguiculariopsis* Rehm.

Rehm (1909) listed "*Mollisiella ilicincola* Mass." on *Myriangium* on *Ilex* in England, "*Cenangium ravenelii* (Berk. & Br.) Sacc." on *Patellaria nigro-cinnabarina* Schw. (= *Rhytidhysteron rufulum* (Spreng. : Fr.) Speg.) in North America, and "*Lachnellula hysterigena* (Berk. & Br.) Sacc." on *Hysterium* (= *R. rufulum*) in Sri Lanka (as Ceylon) as synonyms. [The second and third species treated by Rehm as synonyms are accepted as distinct species in this paper.] Only three additional combinations in *Unguiculariopsis* appear to have been provided since the genus was erected (Korf, 1971; Zhuang, 1987). *Peziza ilicincola* is also the type of the names of several other taxa.

In 1887 Phillips established *Mollisia* subgen. *Mollisiella* Phill. and included nine unrelated species in his subgenus. *Mollisia* (*Mollisiella*) *ilicincola* (Berk. & Br.) Phill. was one of them. In his book Phillips did not typify the subgenus (Phillips, 1887).

In 1889 Saccardo picked up Phillips's subgeneric epithet and transferred it to the genus *Pseudohelotium* Fckl. as *Pseudohelotium* subgen. *Mollisiella* (Phill.) Sacc. Saccardo accepted three species when he published the combination, including two Phillips had placed in his subgenus, *P. ilicincola* (Berk. & Br.) Sacc. and *P. hydnicola* (Berk. & Br.) Sacc. Again no type was designated for the subgenus (Saccardo, 1889).

When Rehm (1892) published *Mollisiella myriostylidis* Rehm, he pointed out in his discussion that Phillips's *Mollisia* subgenus *Mollisiella* must be raised to generic rank. Although I do not consider *Mollisiella myriostylidis* congeneric with *Peziza ilicincola* , which was later chosen as the type of *Mollisia* subgen. *Mollisiella*, this was the first time that Phillips's subgenus *Mollisiella* was used at generic rank. The type of the genus was still undesignated.

Massee (1895), apparently unaware of Rehm's prior action, independently raised Phillips's subgenus *Mollisiella* to generic rank as "*Mollisiella* Mass." He included the same two original species as did

Saccardo (1889), *M. ilicincola* (Berk. & Br.) Mass. and *M. hydnicola* (Berk. & Br.) Mass. in the genus. Shortly afterwards, he (Massee, 1896) synonymized *Peziza hysterigena* Berk. & Curt. and *Peziza ravenelii* Berk. & Br. with *M. ilicincola*. He also mentioned Martin 460 as belonging to this species, but this was later published as the type of *Encoeliella australiensis* Höhn.(Höhnel, 1910). These three species are treated as distinct from *Peziza ilicincola* in this paper.

Saccardo (in Saccardo & Saccardo, 1906) raised, for the third time, Phillips's subgenus *Mollisiella* to generic rank as "*Mollisiella* Sacc." and included three additional species.

In 1909 Rehm published his monotypic genus *Unguiculariopsis*. Automatically *U. ilicincola* became the type of this genus (Voss, et al., 1983).

A year after *Unguiculariopsis* Rehm was published, von Höhnel (1910) erected another genus, *Encoeliella* Höhn., to accommodate two species, *E. ravenelii* (Berk. & Curt.) Höhn. and *E. australiensis*. He disagreed with Massee (1896) and with Rehm (1909), who had synonymized *Peziza hysterigena* and *P. ravenelii* with *P. ilicincola*, and believed that two distinct genera were involved. He synonymized *P. hysterigena* Berk. & Br. 1873 with *P. ravenelii* Berk. & Curt. 1875, mistakenly thought that *P. ravenelii* was an older name than *P. hysterigena*, and stated that the correct specific name was *Encoeliella ravenelii*. His description of *E. ravenelii* was, however, totally based upon the morphology of *P. hysterigena*. *Peziza hysterigena* and *P. ravenelii* are quite different fungi and though both are on the same host, they occur in geographically distant areas. *Encoeliella* was not clearly typified when it was published, but under *Peziza hysterigena*, Höhnel indicated that it constituted a new genus. The two species included are both congeneric with *Peziza ilicincola*, the type species of *Unguiculariopsis*.

For the fungus Rehm described as *Unguiculariopsis ilicincola*, Höhnel (1910) incorrectly used the generic name "*Mollisiella* (Phill.) Sacc." and did not realize that *Mollisiella* (Phill.) Rehm 1892, *Mollisiella* (Phill.) Mass. 1895, and *Mollisiella* (Phill.) Sacc. 1906 are all illegitimate later homonyms of *Mollisiella* Boud. 1885. He did, however, designate the first species listed by Phillips, *Mollisia ilicincola*, as "der Typus des subgenus *Mollisiella* Phillips." There is now a growing body of evidence pointing to Höhnel's typification statements as being based on the "first species rule," which is specifically outlawed by the ICBN. Four years later, Rehm accepted Höhnel's treatment and erroneously abandoned his genus *Unguiculariopsis*, listing *U. ilicincola* as a synonym of *Mollisiella ilicincola* (Rehm, 1914).

In 1931, Clements and Shear designated "*Mollisiella ilicincola* (Berk. & Br.) Sacc." as the type of "*Mollisiella* Sacc." and listed *Unguiculariopsis* Rehm as a synonym of it (Clements & Shear, 1931). They thus made the same mistake as had Rehm (1892, 1914), Massee (1895), Saccardo (1906), and Höhnel (1910), in not recognizing that *Mollisiella* was an unavailable name. Seaver (1939) redesignated the type of "*Mollisiella* (Phill.) Massee" as *Peziza ilicincola*. I accept Clements and

Shear's typification as first typification of Phillips's subgeneric epithet at any rank or position.

It now becomes necessary to present a brief discussion of the two *Mollisiellae* in this paper. *Mollisiella* Boud. was erected with its principal species *Mollisia perparvula* (Karst.) Karst. (Boudier, 1885). According to Article 10 of the current ICBN, the type of the name of a genus must be chosen from the types of one or more of the names definitely included when the genus was published. Since *Mollisia perparvula* is the only species name mentioned by Boudier (1885), it must be adopted as the type of Boudier's genus. The type specimen of *M. perparvula* has been examined, and my examination indicates that it is a *Mollisia* with a short stalk and is thus quite different from Phillips's *Mollisia (Mollisiella) ilicincola* (Korf & Zhuang, 1987). We must use the generic name *Mollisiella* in the sense of Boudier (1885). When Boudier took up the name *Mollisiella* later (Boudier, 1907), he excluded the holotype of his 1885 genus, and automatically created a later homonym, *Mollisiella* Boud. 1907, which has apparently never been typified.

In 1980, the genus *Unguiculariopsis* was reduced to subgeneric rank as *Hyalopeziza* Fckl. subgen. *Unguiculariopsis* (Rehm) Korf & Kohn (Korf & Kohn, 1980). This name is incorrect, for the authors should have transferred Phillips's available subgeneric epithet.

In summary, *Peziza ilicincola* is the type of *Mollisia* subgen. *Mollisiella* Phill., of *Pseudohelotium* subgen. *Mollisiella* (Phill.) Sacc., of *Mollisiella* (Phill.) Rehm, of *Unguiculariopsis* Rehm, and of *Hyalopeziza* subgen. *Unguiculariopsis* (Rehm) Korf & Kohn (Phillips, 1887; Saccardo, 1889; Rehm, 1892, 1909; Clements & Shear, 1931; Korf & Kohn, 1980). The studies reported here convince me that *Unguiculariopsis* Rehm (1909) is an acceptable genus, in contrast to its subgeneric treatment by Phillips (1887), Saccardo (1889), and Korf & Kohn (1980). *Mollisiella* (Phill.) Rehm (1892) is an obligate synonym of *Unguiculariopsis* Rehm and is an unavailable later homonym. I disagree with Höhnel (1910), who separated *Encoeliella* as a distinct genus, and place this generic name in synonymy with *Unguiculariopsis*, in agreement with the treatments by Korf (1973), Raschle (1977), and Baral and Krieglsteiner (1985).

Unguiculariopsis ilicincola was also treated as a member of the genus *Pithyella* by some mycologists (Boudier, 1907; Dennis, 1960, 1968, 1978; Moser, 1963). The type specimen of the type species of the genus *Pithyella* Boud. (1885), *P. hypnina* (Quél.) Boud., is apparently lost. Korf and Zhuang (1987) have shown that this generic name must be adopted for species with marked, spherical ascospores that occur on mosses, ferns, and fungi, previously treated as *Helotiopsis* Höhn. One of the species placed in *Pithyella* by Boudier (1907) was the type species of *Unguiculariopsis*, which has no close relationship to *Pithyella* Boud.

In his study of Hyaloscyphaceae, Raitviir (1970) put the species which have light-colored apothecia, glassy, subhyaline, hooked hairs, and hooked paraphyses in the genus *Unguiculella* Höhnel. One of the species, *U. robergei* (Desm.) Dennis, having a brick-red hymenium, brick-red to brownish hairs, and filiform paraphyses, does not fit the generic description of *Unguiculella* (Höhnel, 1906; Dennis, 1949; Raitviir, 1970), but it is a good species of *Unguiculariopsis*. *Unguiculariopsis* is distinguished from *Unguiculella* in excipular structure, excipular cell color, hair color, and shape of paraphyses.

FUNGICOLOUS HABIT, HOST SPECIFICITY AND GEOGRAPHIC DISTRIBUTION OF *UNGUICULARIOPSIS*

FUNGICOLOUS HABIT

Throughout my study of the genus *Unguiculariopsis*, a phenomenon which has been regularly noticed is that species of this genus are clearly fungicolous or at least intimately associated with other fungi. *Unguiculariopsis* species either grow directly on fruit bodies of the fungal hosts, as happens in most species, or occur on mycelia of the host fungi. The word "host" may be defined as "a living organism harboring a parasite; sometimes, as in 'host index,' in a general sense covering certain substrata" (Hawksworth, et al., 1983). In this paper it refers to fungi or lichens which support the growth and reproduction of *Unguiculariopsis* species, and which may be either living organisms or decaying fruit bodies. Although ascomycetes appear to be the hosts in most cases, ascomycetous lichens and possibly deuteromycetes (presumed to be ascomycetous anamorphs) are also involved. Among sixteen species recognized, fifteen are fungus-associated and one is lichenicolous (Fig. 1).

The relationship between *Unguiculariopsis* and its hosts, which are sometimes not parasitic, is somewhat similar to hyperparasitism. Although the word "hyperparasite" is defined as "a parasite parasitic on another parasite" (Hawksworth, et al., 1983), the parasitism of the host fungus has not been critically weighed by most workers. A hyperparasite taken in this broad sense is perhaps better termed a mycoparasite, which merely means one fungus parasitic on another. Hyperparasitic fungi have been divided into necrotrophic and biotrophic groups, and the latter was further subdivided into destructive or balanced parasites, depending on whether they kill the hosts (Barnett & Lilly, 1958; Boosalis, 1964; Deacon, 1984). In the discussion of the hyperparasites of *Phyllachora*, Parbery (1978) indicated that there is possibly a gradation between necrotrophic hyperparasites and saprophytes. Hawksworth (1980) reported that infected specimens of *Lecanora* species do not appear to be markedly damaged by *U. thallophila* (Karst.) Zhuang. Even when the apothecia of *Unguiculariopsis* are numerous, the normal grey color of the lichen thallus is retained, and microscopic examination shows the algal cells also to be healthy.

Hyperparasitic nutrition has been studied in balanced hyperparasites and in a few destructive ones. There are three different ways to derive nutrients from cells of the host fungi: 1) production of haustoria within host cells, such as the mode of some species of *Dispira* and *Piptocephalis*

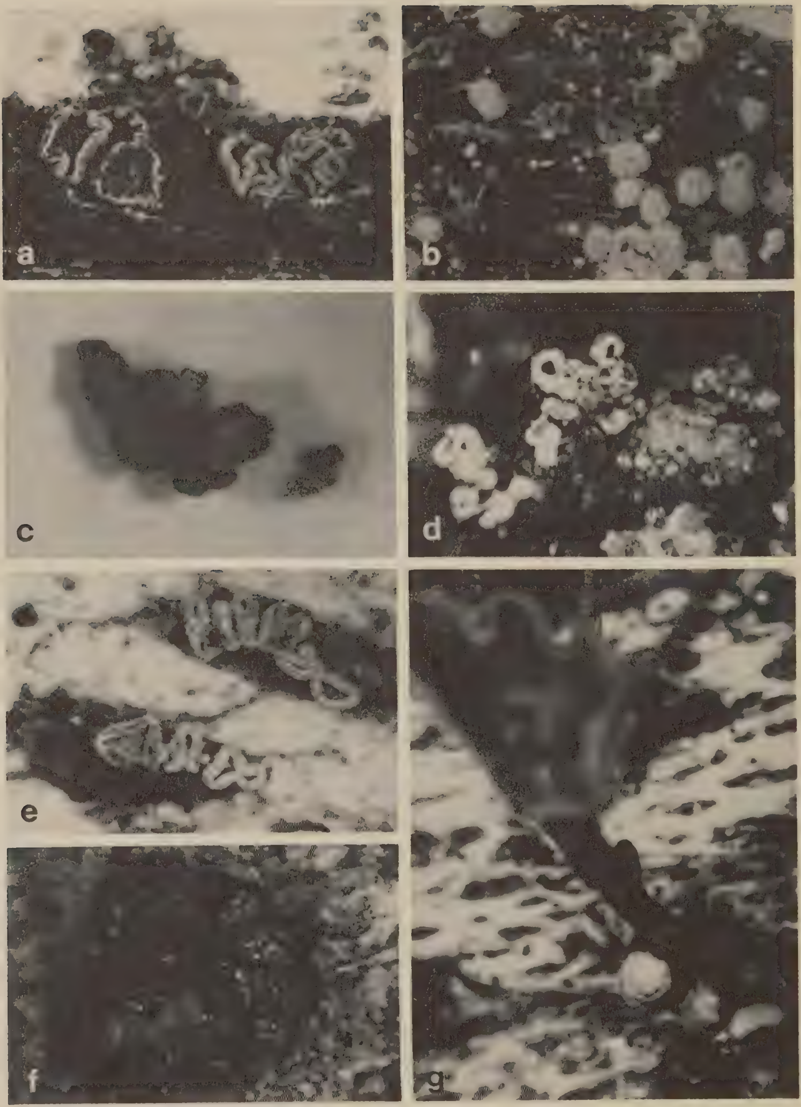
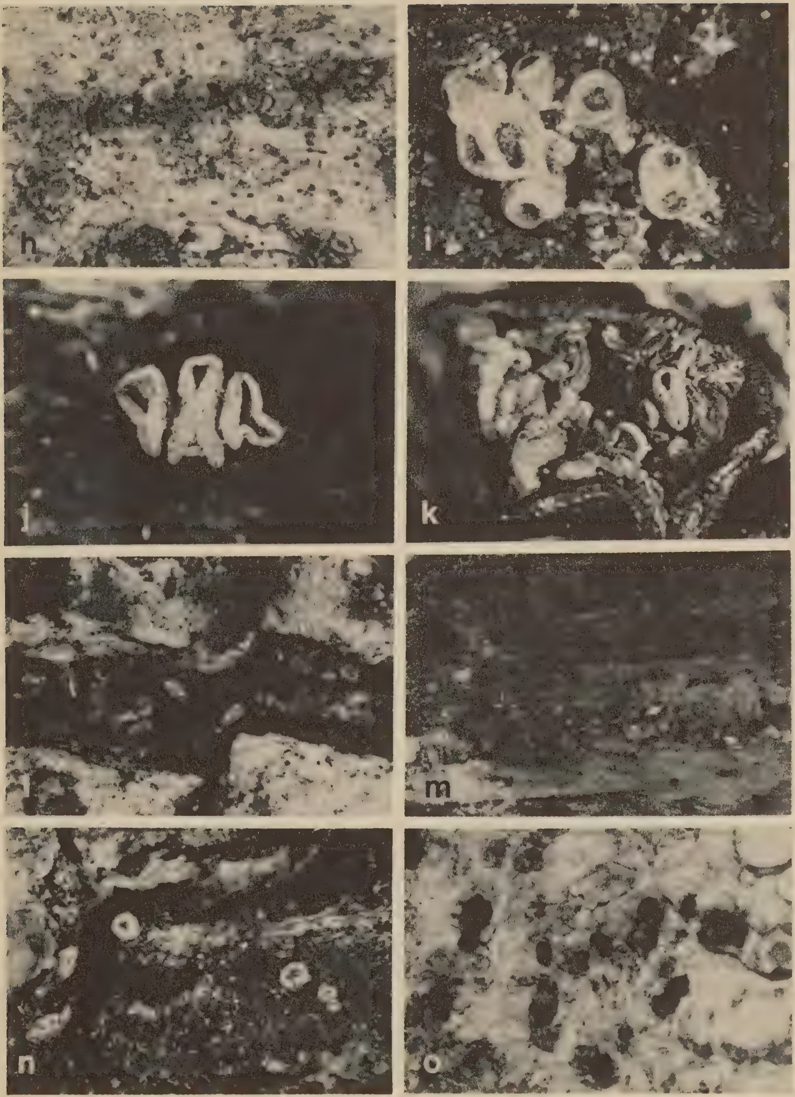


FIG. 1. *Unguiculariopsis* species and their hosts: **a**. *U. acerina*, **b**. *U. adirondacensis*, **c**. *U. australiensis*, **d**. *U. godroniicola*, **e**. *U. hysterigena*, **f**. *U. ilicincola*, **g**. *U. infundibuliformis*, **h**. *U. livida*, **i**. *U. parasitica*, **j**. *U. ravenelii* subsp. *ravenelii*,



k. *U. ravenelii* subsp. *hamata*, **l.** *U. rehmii*, **m.** *U. robergei* subsp. *robergei*, **n.** *U. robergei* subsp. *coelomyceticola*, **o.** *U. thallophila*; all x 17.5. **a**, **b**, **d**, **g**, **h**, **n**, **o** from holotype; **c**, **i**, **l**, **m** form isotype, **e** from CUP-CH 259; **f** from ZT; **j** from R.P.K. 2349, **k** from FH-Cheo 640.

(Ayers, 1935; Dobbs & English, 1954; Richardson & Leadbeater, 1972); 2) dissolution of host walls in contact with the parasites, reported in *Chaetocladium* and *Parasitella* species (Barnett & Lilly, 1958; Boosalis, 1964); 3) production of small, specialized, contact cells at the tips of mycoparasitic hyphae, as in the contact cells produced by *Calcarisporium parasiticum* Barnett (Barnett & Lilly, 1958). It has been reported that *Gliocladium roseum* (Link) Bainier, a destructive mycoparasite, invades its hosts in different ways which vary by host species, host age, and specific host structure involved (Barnett & Lilly, 1962).

On the basis of my observations of sixteen species of *Unguiculariopsis* and several other fungicolous discomycetes, I believe that the mode of nutrition is determined by the composition of each individual fungal pair and varies from biotrophic to necrotrophic. The collections of *Unguiculariopsis* that I have studied are mostly dried, herbarium specimens; only four taxa were observed in fresh condition. *Unguiculariopsis* species do not destroy their hosts, and thus they are similar to balanced parasites. Normal fruit bodies and mature spores are present both in the fungal host and in *Unguiculariopsis*. But two possibilities are proposed. First, some species of this genus may attack only mature hosts, and the fruit bodies of the hosts are not destroyed by late invasion of *Unguiculariopsis*. *U. ravenelii* (Berk. & Curt.) Zhuang & Korf in Zhuang, for example, usually does not occur on the vigorously growing host, but only on fully mature or perhaps slightly decaying hysterothecia of the host fungus. The ascospores germinate on artificial medium. Germ tubes grow very slowly, but the fungus hardly produces a colony before death of the culture (Zhuang, 1987). Second, *Unguiculariopsis* species may develop their fruit bodies together with their hosts. In a fresh collection of *U. adirondacensis* Zhuang, the host grows as vigorously as does the parasite. This species resembles biotrophic hyperparasites, and it could not be cultured. Its ascospores when shot on artificial medium did not germinate.

The ways by which *Unguiculariopsis* species obtain nutrition from their hosts are not clear. Haustoria were not observed to be produced by any species of *Unguiculariopsis*. Dissolution of the host walls in contact with *Unguiculariopsis* is not easy to detect under natural conditions. But I have seen in sections of *U. ravenelii* that tissues of the apothecial base gradually merge into the host hymenium. At a certain point one can hardly distinguish whether the tissue is host or *Unguiculariopsis*. The production of specialized contact cells at the tips of mycoparasitic hyphae has also not been confirmed, even though I have seen a few, small, short, septate hyphae connecting the receptacle surface of *U. livida* (Bacc.) Zhuang with the pseudothecium of its host.

In contrast to *Unguiculariopsis*, the species of *Parencoelia*, a genus of clearly hyperparasitic fungi, may affect on development of the host fungi and seem to be destructive. The stromata of *Phyllachora* and of *Cocconia* parasitized by *Parencoelia* do not give rise to normal spore-bearing ascocarps (Zhuang, 1988a).

HOST SPECIFICITY

Fungus-inhabiting fungi have been catalogued in the famous work, "*Enumeratio Systematica Fungorum*" (Oudemans, 1919). Those records indicate that one fungal species may be restricted to a single host fungus or have a relatively broad host range. The host ranges of *Unguiculariopsis* species seem to be narrow, perhaps restricted to single species. Collections from the same host species share many morphological similarities, while those from different hosts are often diverse.

Host specificity has been useful in locating additional specimens of a species by examining collections of the host species in herbaria, and finding the fungicolous discomycete which was unwittingly collected at the same time. Although prior to this study *U. hysterigena* (Berk. & Br.) Korf was known only from the holotype taken in Ceylon, three additional collections all from a southern island of China have been found by examining several hundred specimens of its host, *Rhytidhysteron rufulum*. A second species, *U. dimorpha* (Seaver) Zhuang, occurs on beaked pyrenomycetes. When several specimens on a so-called *Eutypa*, filed under the names *Cenangium episphaerium* Schw. and *C. australe* Pat. (non *Cenangium australe* Speg.), were borrowed, a similar host fungus was consistently found. The fungicolous discomycete on that host species turned out to be *U. dimorpha*. The true *C. episphaerium* is also fungicolous but occurs on a different host, differs conspicuously from *U. dimorpha*, and is certainly not congeneric. A third species, *U. parasitica* (Fckl.) Zhuang on *Eutypa lata* (Pers.) Tul., is closely related to *U. dimorpha*, and shares many morphological features in both teleomorph and anamorph, but is undoubtedly different. I suspect that the factors which led to divergence of these two species are either geographical separation or the differences in the host fungi from which they absorb their nutrients. Although all known species select their own host(s), I prefer not to stress the effects of host range in classification. *U. hysterigena* and *U. ravenelii* are morphologically recognizable even though they occur on the same fungal genus (*Rhytidhysteron*), and the same situation exists with *U. australiensis* (Höhn.) Zhuang and *U. ilicincola* (on *Myriangium*).

GEOGRAPHIC DISTRIBUTION

The genus *Unguiculariopsis* is cosmopolitan. The distribution of each *Unguiculariopsis* species depends upon that of its host fungus. The hosts include a variety of Ascomycetes, Deuteromycetes, and lichens that occur in tropical, subtropical, and temperate areas. *U. australiensis* has only been reported from Australia. *U. dimorpha*, *U. hysterigena*, *U.*

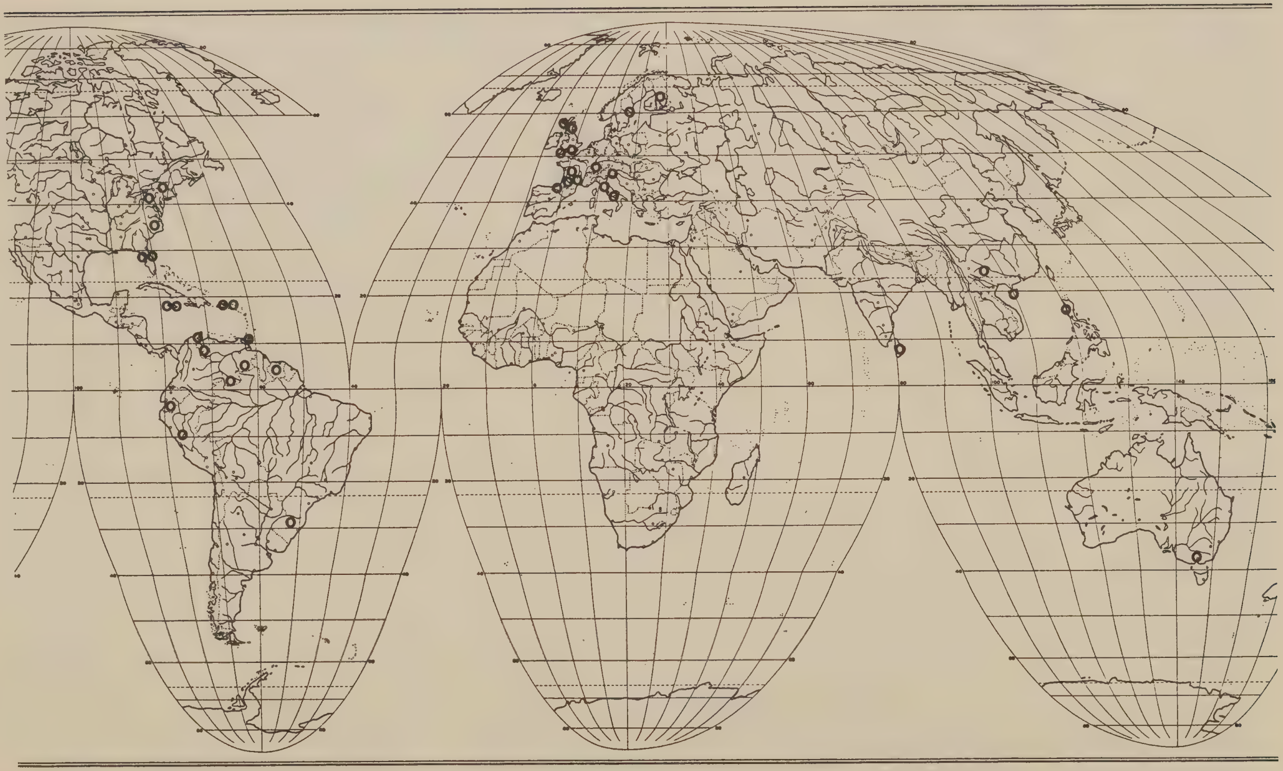


FIG. 2. World distribution of *Unguiculariopsis*.

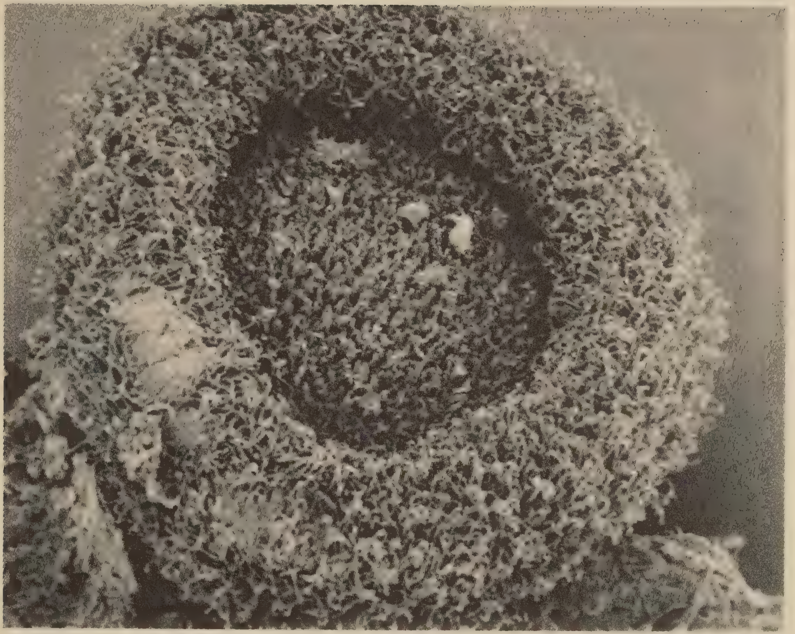
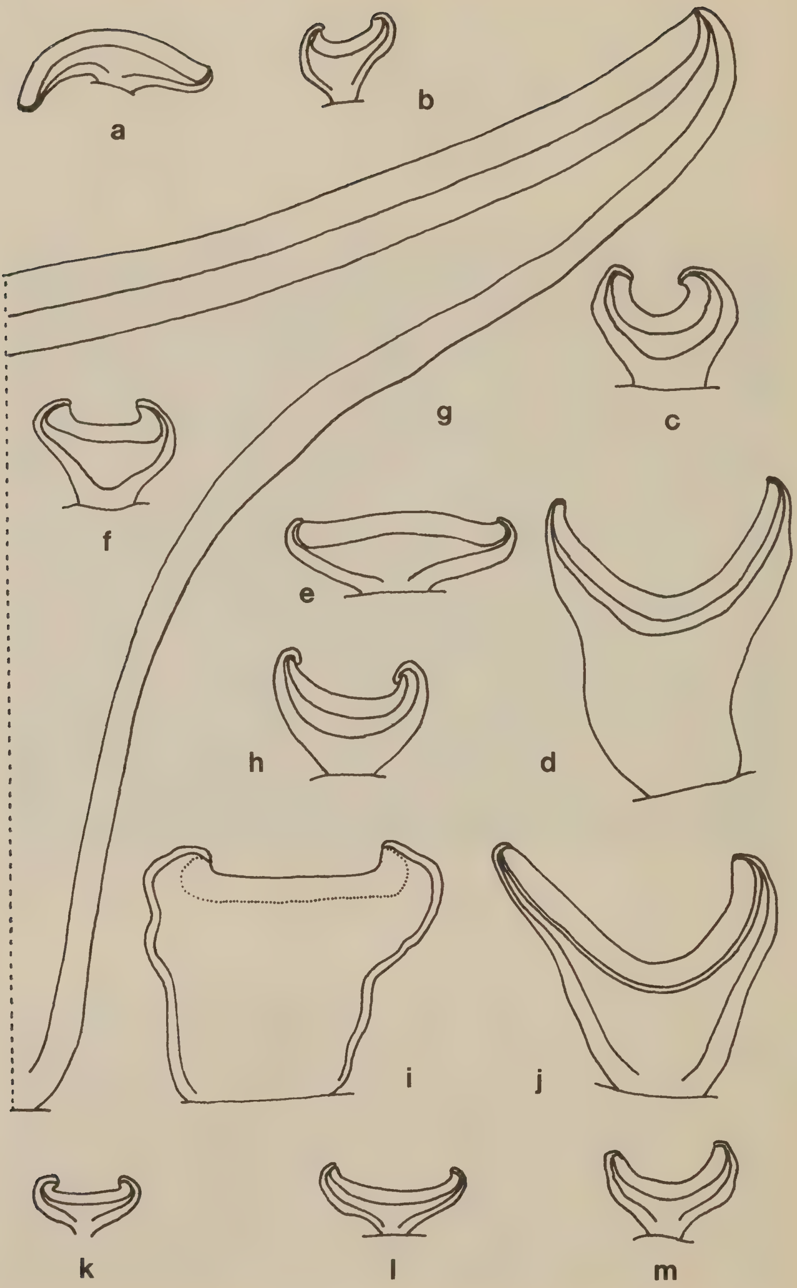


FIG. 3. Scanning electron micrograph of an apothecium of *Unguiculariopsis acerina* (holotype). x 270.

infundibuliformis (Durand) Korf, *U. jamaicensis*, and *U. ravenelii* subsp. *ravenelii* are in subtropical to tropical regions. *U. infundibuliformis* is perhaps pan-tropical, for specimens of this fungus have been collected from Trinidad and the Philippines. *U. ravenelii* subsp. *hamata* (Chen.) Zhuang is found in China, France and Surinam. The rest of the species are located mainly in temperate areas, especially in Europe, where nine species are found (Fig. 2). I suspect that the genus is not as rare as would appear and that more taxa will be discovered. The reason that limited collections have been found is that the apothecia of *Uuguiculariopsis* are usually small, inconspicuous, and easily overlooked. I hope that this monograph will call attention to this group of fungi and will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stimulate research on the fungus-fungus interaction of fungicolous fungi and of putative mycoparasites.

MORPHOLOGY OF *UNGUICULARIOPSIS*

The apothecia of this genus are cupulate, discoid, or infundibuliform, sometimes unequal-sided, and frequently have the margin strongly enrolled (Fig. 3). The size varies from one species to another. *Unguiculariopsis dimorpha*, *U. infundibuliformis* and *U. ravenelii* may be recognized in the field by the naked eye. Most species are very easily overlooked because of their small size and because of the more conspicuous host fungus. The apothecia are usually 0.1-1.0 mm in diam, but those of *U. infundibuliformis* may reach 4 mm. Stipes are absent in most species, whereas the apothecia are shortly or broadly stipitate in *U. godroniicola* Zhuang, *U. parasitica,* and *U. ravenelii*, and long-stipitate in *U. infundibuliformis* (Fig. 4). Apothecia appear solitary or several in a fascicle on the host fungi or sometimes on the same substrate associated with their hosts. Since fresh materials were not available for most species, the apothecial colors that I report are often from dry specimens. The hymenial colors of dry specimens are commonly grayish brown, chestnut brown, warm brown, vinaceous brown, dirty orange, or dark brown. The hymenial colors in fresh specimens vary with species from pale yellow, orange, grayish, grayish brown, pale brown, or reddish to brick-red, or have a purple to rosy tint. The receptacle surfaces are furfuraceous, downy or roughened depending upon the length and distribution of hairs. The colors of the receptacle when dry vary from grayish white, light vinaceous brown, or grayish brown to cinnamon-brown, and when fresh are white, dirty white, light vinaceous, or brownish. A single collection of *U. adirondacensis* was examined in the fresh condition: the hymenium is vinaceous, and the receptacle is light vinaceous. Upon drying, the color becomes slightly darker. Three fresh collections of *U. ravenelii* subsp. *ravenelii* showed an orange hymenium and a grayish brown to light vinaceous receptacle. The fresh apothecia of *U. ravenelii* subsp *hamata* collected in France have a vinaceous tint.

Hairs are present in all members of *Unguiculariopsis*. Hairs in most species have a swollen base and a fine, curved apex (Fig. 5). In *U. australiensis* and *U. godroniicola* they are wide at the base and taper toward the tip, with a fine, hooked apex. Hairs are short, only 13-65 µm long, glassy-walled, nonseptate in most species, and occasionally uniseptate in *U. australiensis*. The colors are light brown to pale brown at

FIG. 4. Apothecial shapes of *Unguiculariopsis* species: **a**. *U. acerina*, **b**. *U. adirondacensis*, **c**. *U. australiensis*, **d**. *U. godroniicola*, **e**. *U. hysterigena*, **f**. *U. ilicincola*, **g**. *U. infundibuliformis*, **h**. *U. livida*, **i**. *U. parasitica*, **j**. *U. ravenelii*, **k**. *U. rehmii*, **l**. *U. robergei*, **m**. *U. thallophila*. All from type specimen except **m** from H-Herb. Karsten 2579. From top to bottom, three zones showing: hymenium, medullary excipulum and ectal excipulum; four zones showing: hymenium subhymenium, medullary excipulum and ectal excipulum. x 50.

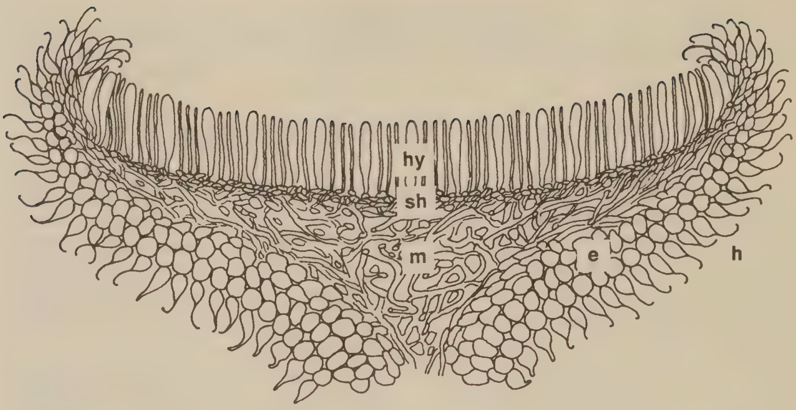


FIG. 5. **Diagram of apothecial anatomy of *Unguiculariopsis*: hymenium (hy), subhymenium (sh), medullary excipulum (m), structure of ectal excipulum (e), hairs (h).**

the swollen base and subhyaline to pale brown at the fine apices. The apices of hairs have a lumen in most species but are solid in *U. acerina* Zhuang, *U. hamatopilosa* (Graddon) Zhuang, *U. ravenelii*, and *U. robergei* Korf & Zhuang. Hairs are distributed on the whole receptacle surface in *U. acerina*, *U. australiensis*, *U. hamatopilosa*, *U. ilicincola*, *U. livida*, *U. ravenelii*, and *U. rehmii*; and mainly at the margin and on the upper flanks of apothecia in *U. dimorpha*, *U. godroniicola*, *U. hysterigena*, *U. infundibuliformis*, *U. parasitica*, *U. robergei* subsp. *coelomyceticola* Zhuang, and *U. thallophila*. Their surfaces are smooth in most species, but in *U. hysterigena* there are granules on the surface which dissolve in aqueous KOH. Histochemical reactions of hairs with aqueous KOH solution, Melzer's reagent, Congo red, and cotton blue have been reported in some genera of the Hyaloscyphaceae (Korf & Kohn, 1980; Huhtinen, 1987). Generally, the glassiness of hairs of *Unguiculariopsis* species is not influenced by treatment with 10% aqueous KOH solution, and neither is the Congo red-permeability of the hair walls. The hair walls of *U. hysterigena* may become slightly less glassy after KOH treatment. Hairs of this genus are not dextrinoid but in some species their bases may become faintly to strongly purple in Melzer's reagent.

The anatomical composition of an apothecium of this genus may be of three parts, *i.e.*, hymenium, medullary excipulum, and ectal excipulum; or of four parts, with an additional subhymenium (Fig. 4). Ectal excipula are of textura globulosa to textura angularis (Figs. 5, 6). Cells are brown and somewhat thick- and glassy-walled, isodiametric to ellipsoid, and may vary from 3 µm to 22 µm in diam. Cells in the outermost layer are in a slightly looser arrangement than those inside. The axes of the ectal cells in some species may be perpendicular to the exterior of the apothecium. Pustules

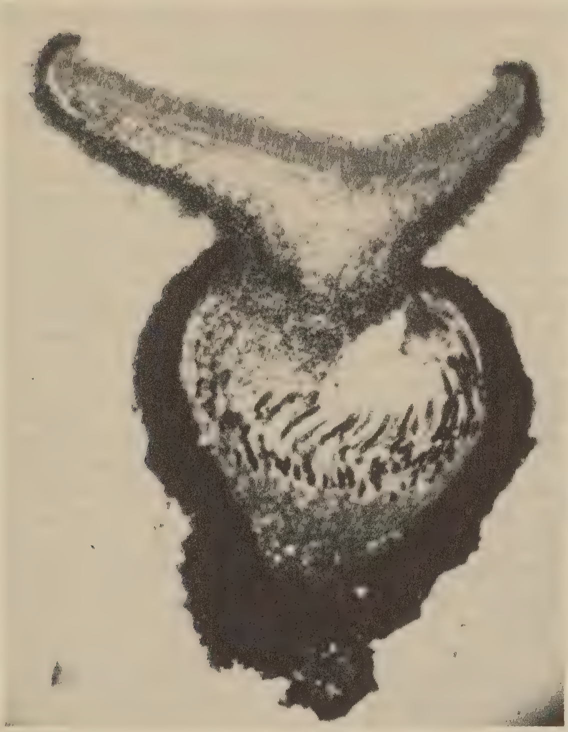


FIG. 6. Photograph of transverse section of an apothecium of *Unguiculariopsis hysterigena* arising from the hymenium of *Rhytidhysteron rufulum* (CUP-CH 259), x 100.

are present on receptacles of *Unguiculariopsis australiensis* and *U. ravenelii* subsp. *ravenelii,* but are only noticeable in section. Medullary excipula are of textura intricata (Figs. 5, 6), rarely of textura angularis. Hyphal walls are somewhat refractive. The thickness of the medullary excipulum varies from one species to another. Subhymenia are of textura intricata and can be recognized in *U. infundibuliformis* and in both subspecies of *U. ravenelii.*

Asci are inoperculate, 8-spored, 6-spored, 4-spored, or 2-spored, occasionally with 5 or 7 spores. Most species have eight spores in an ascus. *U. hamatopilosa* is the only species with 2-spored asci. The young asci of *U. robergei* subsp. *robergei* are 8-spored, but at maturity, there are only four spores accompanied by cytoplasm in an ascus. The shapes of asci differ among species: cylindrical in *U. australiensis*, *U. dimorpha*, *U. hysterigena*, *U. ilicincola*, *U. infundibuliformis*, *U. livida*, and *U. ravenelii*; fusoid in *U. rehmii*; and clavate in *U. acerina*, *U.*

adirondacensis, *U. hamatopilosa*, *U. robergei*, and *U. thallophila*. Asci arise commonly from croziers. The iodine reactions of ascus pores in the species of *Unguiculariopsis* are uniformly J–, *i.e.*, pore walls do not turn blue in Melzer's reagent with or without KOH pretreatment. Asci shoot spores eight in a group in *U. adirondacensis* but in groups of varying numbers in both subspecies of *U. ravenelii*.

Ascospores are unicellular, hyaline, subhyaline to pale yellow, smooth- and thin-walled, spherical, subspherical or ellipsoid. Guttules can be seen in the spores of all species. Both spherical-spored and ellipsoid-spored species have uninucleate ascospores, and the nuclei of the ellipsoid-spored species stain in Belling's iron-acetocarmine. Spores within asci are uniseriate in species with cylindrical asci, biseriate or irregularly biseriate in species with fusoid or clavate asci. The ascospores are usually less than 6 µm in diam in spherical-spored species and not longer than 10 µm in ellipsoid-spored species.

Paraphyses are hyaline, filiform, mostly septate, some of them branched, slightly to strongly deformed at the apex, and about 2 µm wide. Occasionally, some paraphysis apices are hair-like and protrude from the hymenium surface. The length of paraphyses varies from one species to another. Their apices are shorter than, equal to, or longer than the asci.

A *Deltosperma* anamorph is produced in *U. dimorpha*, *U. infundibuliformis*, and *U. parasitica*. No anamorph has been reported in other species of this genus.

TAXONOMY OF *UNGUICULARIOPSIS*

TAXONOMIC STATUS OF *UNGUICULARIOPSIS*

A historical review of the taxonomy of *Unguiculariopsis* shows that the species of this genus have been placed by early and recent mycologists in five families (eighteen genera) of three orders: Dermateaceae (*Dermatea*, *Mollisia*, *Mollisiella*, *Pyrenopeziza*, *Trochila*), Hyaloscyphaceae (*Hyalopeziza*, *Lachnella*, *Lachnellula*, *Unguiculella*), Leotiaceae (*Cenangium*, *Encoelia*, *Encoeliella*, *Pithyella*, *Pseudohelotium*, *Unguiculariopsis*), Odontotremataceae (*Skyttea*), Pezizaceae (*Peziza*), and *Midotis* (the type is lost and its taxonomic position is not clear).

That *Unguiculariopsis* has long been placed in the Hyaloscyphaceae is probably because of the presence of hairs. My examination of sixteen species of *Unguiculariopsis* has convinced me that this genus must be transferred from the Hyaloscyphaceae to the Leotiaceae. I think that the presence of short, specialized hairs is less important than the apothecial structure in taxonomy of this group of fungi, and I treat the presence of hairs as one of the generic characters which differentiate *Unguiculariopsis* from other taxa of the Encoelioideae.

The family name Hyaloscyphaceae, in which *Unguiculariopsis* has been traditionally placed, was erected to accommodate genera with the following characteristics: apothecia are superficial or rarely erumpent, often very small, short- or long-stipitate, light-colored, soft fleshy; excipula of textura prismatica, cells thin-walled, hyaline, or rarely with colored walls, outside almost always with distinct, more frequently rough hairs; asci medium to large, clavate, mostly with a positive iodine reaction; ascospores oblong to nearly needle-shaped, hyaline, simple or septate; paraphyses filiform or lanceolate, hyaline or with colored contents; anamorph very rarely found (Nannfeldt, 1932). This concept has been followed, with only minor changes, by many mycologists (Dennis, 1949; Raitviir, 1970; Korf, 1973; Raschle, 1977). They all agree, in general, that apothecia of this family are soft-fleshy, excipula are mainly of textura prismatica, and receptacle surfaces are covered with distinct hairs, especially at the margin.

The Hyaloscyphaceae, as a segregate of the old "Helotiaceae," is conspicuously different from the current Leotiaceae in the anatomical structure of the excipulum and in the presence of hairs on the receptacle surface. We have to accept the presence of hairs as a useful character for distinguishing the two families until we find a better substitute. Nevertheless, based upon the current understanding, it is difficult to say whether this character indicates any real affinity among fungi of the Helotiales.

Sections of *Unguiculariopsis* species show that this genus should be a member of the subfamily Encoelioideae of the Leotiaceae. Unlike the Hyaloscyphaceae, the excipular structure is not of textura prismatica, but of textura globulosa to textura angularis; the cells of the ectal excipulum are not hyaline and thin-walled, but brown and thick-walled; furthermore, the cells in the outermost layer of the excipulum are usually loosely interconnected. All features mentioned above are typical of the morphology of the Encoelioideae (Nannfeldt, 1932; Dennis, 1956; Korf, 1973; Torkelsen & Eckblad, 1977). Two accepted species of *Unguiculariopsis* had been separated from the others and named *Encoeliella* by Höhnel (1910). Nannfeldt (1932) treated *Encoeliella* as a genus of the Encoelioideae, and stated that the genus was erected to include species related to *Cenangium* (*Encoelia*) with hairy, small apothecia and spherical spores. Actually, *Encoeliella* shares common characteristics with all species of *Unguiculariopsis* and is a later synonym of the latter.

GENERIC DIAGNOSIS

Unguiculariopsis Rehm, Ann. Mycol. 7: 400, 1909.

≡ *Hyalopeziza* Fckl. subgen. *Unguiculariopsis* (Rehm) Korf & Kohn, Mycotaxon 10: 509, 1980.

= *Mollisia* (Fr.) Karst. subgen. *Mollisiella* Phill., Brit. Disc. p. 193, 1887 [lectotype: *Peziza ilicincola* Berk. & Br., selected by Clements & Shear, 1931].

≡ *Mollisia* sect. *Mollisiella* (Phill.) Sacc. (ut "Phill."), Syll. Fung. 8: 291, 1889, pro synon.

≡ *Pseudohelotium* Fckl. subgen. *Mollisiella* (Phill.) Sacc., Syll. Fung. 8: 304, 1889.

≡ *Pseudohelotium* Fckl. sect. *Mollisiella* (Phill.) Mass. (ut "Sacc."), Brit. Fung. Fl. 4: 221, 1895, pro synon.

≡ *Mollisiella* (Phill.) Rehm, Hedwigia 6: 301, 1892. (non *Mollisiella* Boud., Bull. Soc. Mycol. France 1: 120, 1885 [holotype: *Peziza perparvula* Karst.]; nec *Mollisiella* Rehm, in Rabenh. Krypt.-Fl. ed.2, 1(3)[Lief. 36]: 534, 1891, nom. provis. ["type": *Mollisia hamulata* Rehm]; nec *Mollisiella* Boud., Hist. Classif. Disc. Europe p. 141, 1907 [type: non designatus]).

≡ *Mollisiella* (Phill.) Mass. (ut "Massee"), Brit. Fung.-Fl. 4: 221, 1895 (isonym).

≡ *Mollisiella* (Phill.) Sacc. in Sacc. & Sacc., Syll. Fung. 18: 64, 1906 (isonym).

= *Encoeliella* Höhn., Sitzungsber. Kaiserl. Akad. Wiss., Math.-Naturwiss. Kl., Abt. 1. 119: 619, 1910 [holotype: *Peziza ravenelii* Berk. & Curt.].

Apothecium solitary or several in a fascicle, cupulate to discoid, usually with margin enrolled, sessile, broadly stipitate, shortly stipitate, or stipitate, 0.1-4.0 mm in diam; hymenium vinaceous brown, dark brown, or cinnamon-brown when dry, vinaceous or orange when fresh in some species; receptacle surface furfuraceous, grayish white, light vinaceous, vinaceous brown, or cinnamon-brown when dry. Hairs occurring on the whole receptacle surface or only at margin and the upper flanks, with a swollen base and a fine, hooked apex, light brown at base, pale yellow, subhyaline, or hyaline at apex, becoming purple or not in Melzer's reagent with 10% aqueous KOH pretreatment, nonseptate in most species, with lumen or solid at apex, glassy- and somewhat thick-walled, walls smooth or granulate, granules dissolving rapidly in aqueous KOH solution. Ectal excipulum of textura globulosa to textura angularis, cells brown, walls somewhat refractive and thick; medullary excipulum of textura intricata, occasionally of textura angularis, hyphal walls subhyaline to light brown; subhymenium present or indistinguishable. Asci inoperculate, 8-spored, less commonly 2-, 4- or 6-spored, subcylindrical, clavate, or subfusoid, J– in Melzer's reagent with or without KOH pretreatment. Ascospores uniseriate to biseriate, spherical, subspherical, or ellipsoid, unicellular, hyaline or subhyaline to pale yellow, guttulate, uninucleate, smooth-walled. Paraphyses filiform, slightly to strongly deformed at apex, hyaline, simple or branched, septate or nonseptate.

Occurring on or associated with other fungi and lichens.

Anamorph: *Deltosperma*.

HOLOTYPE: *Unguiculariopsis ilicincola* (Berk. & Br.) Rehm.

KEY TO THE SPECIES OF *UNGUICULARIOPSIS*

1. Ascospores spherical to subspherical 2
1'. Ascospores ellipsoid 9
2. Asci subfusoid, paraphyses shorter than asci, on *Cucurbitaria berberidis* . . . . *U. rehmii*
2'. Asci cylindrical, paraphyses not shorter than asci, on other fungi 3
3. Apothecium broadly stipitate, stipe covered with hyphae, on apothecia of *Godronia* sp. . . . . *U. godroniicola*
3'. Apothecium sessile or substipitate, on other fungi 4
4. Asci 31-35 µm long, hairs relatively thin-walled, on ?*Karstenula* sp. . . . . *U. livida*
4'. Asci longer than 35 µm, hairs relatively thick-walled, not on ?*Karstenula* sp. 5
5. Apothecium on *Myriangium* species 6
5'. Apothecium on *Rhytidhysteron* species 7
6. Ascospores spherical, mostly equal to or less than 3.7 µm in diam; hairs wider at base, tapered towards the apex, 30-55 µm long, occasionally with a septum . . . . *U. australiensis*
6'. Ascospores spherical to subspherical, mostly larger than 3.7 µm in diam; hairs with a swollen base, narrowed abruptly toward the apex, less than 33 µm long, nonseptate . . . . *U. ilicincola*
7. Hairs with granules that dissolve in KOH solution, very thick-walled, occurring only at the margin and upper flanks . . . . *U. hysterigena*
7'. Hairs smooth-walled, scattered on the receptacle surface . . . . *U. ravenelii* 8
8. Asci less than 5.0 µm wide, on *Rhytidhysteron rufulum* . . . . *U. ravenelii* subsp. *ravenelii*
8'. Asci up to 6.0 µm wide, on *Rhytidhysteron hysterinum* . . . . *U. ravenelii* subsp. *hamata*
9. Apothecium on thalli of *Lecanora* sp. . . . . *U. thallophila*
9'. Apothecium on other substrates 10
10. Pycnidial anamorph with subtriangular conidia (*Deltosperma*) produced 11
10'. Anamorph unknown 13
11. Apothecium infundibuliform, long-stipitate, up to 4 mm in diam . . . . *U. infundibuliformis*
11'. Apothecium discoid, broadly stipitate, sessile to subsessile, 1-2 mm in diam 12
12. Apothecium broadly stipitate, on *Eutypa lata*. . . . *U. parasitica*
12'. Apothecium sessile to subsessile on beaked pyrenomycetes . . . . *U. dimorpha*

13. Hairs with a lumen at apex, associated with a *Lachnellula*-like fungus . . . . *U. adirondacensis*
13'. Hairs with a solid apex, associated with other fungi 14
  14. Medullary excipulum of textura intricata, with cell walls subhyaline, marginal hairs with a curved apex . . . . *U. robergei* 15
  14'. Medullary excipulum of textura angularis to textura intricata, with cell walls brown, marginal hairs with a coiled apex 16
15. Ascospores 4.4-7.0 X 2.7-3.5 µm, hairs 44-65 µm long, associated with *Amphisphaerella xylosti* . . . . *U. robergei* subsp. *robergei*
15'. Ascospores 6.3-10.2 X 2.2-3.0 µm, hairs 22-45 µm long, associated with a *Septoriella*-like fungus . . . . *U. robergei* subsp. *coelomyceticola*
  16. Mature asci 6 to 8-spored, hairs 28-37 µm long . . . . *U. acerina*
  16'. Mature asci 2 to 4-spored, hairs 22-30 µm long *U. hamatopilosa*

ACCEPTED SPECIES

1. **Unguiculariopsis acerina Zhuang, sp. nov.** (Fig. 7)

Ab U. robergei ascsosporis minoribus, ascis 4-sporis deficientibus, excipulo medulloso varie ex textura angulari et intricata et non solummodo ex textura intricata composito, discrimine manifesto excipuli medullosi et excipuli ectalis absente differens.

Apothecium discoid to flat with an undulate margin when dry and strongly convex when rehydrated, sessile with apothecial base inserted into the substrate, less than 1 mm in diam; hymenium vinaceous brown when dry; receptacle surface furfuraceous, grayish brown when dry. Hairs scattered from margin to the base of apothecium, smooth-walled, with a swollen base and a fine, hooked to coiled apex, brown at base, lighter towards the apex, not becoming purple in Melzer's reagent with 10% KOH pretreatment, nonseptate, mostly with a solid apex, very few with lumen extending to the apex, 28-37 µm long. Ectal excipulum of textura angularis to textura globulosa, 13-23 µm thick, cells brown, somewhat thick-walled, isodiametric to ellipsoid, if isodiametric ca. 4-12 µm in diam, if ellipsoid up to 14 µm long, axes of cells perpendicular to the outer surface. Medullary excipulum of textura angularis to textura intricata, difficult to separate from ectal excipulum; cells brown, ellipsoid. Subhymenium indistinguishable. Asci 8-spored, occasionally 6- or 7-spored, clavate, J–, pore walls not turning blue in Melzer's reagent with 10% KOH pretreatment, 30-38 x 4.5-5.0 µm, arising from croziers. Ascospores biseriate, ellipsoid, biguttulate, subhyaline, 4.6-6.4 x 1.8-2.4 µm. Paraphyses filiform, 1-septate near base, sometimes branched at very base,

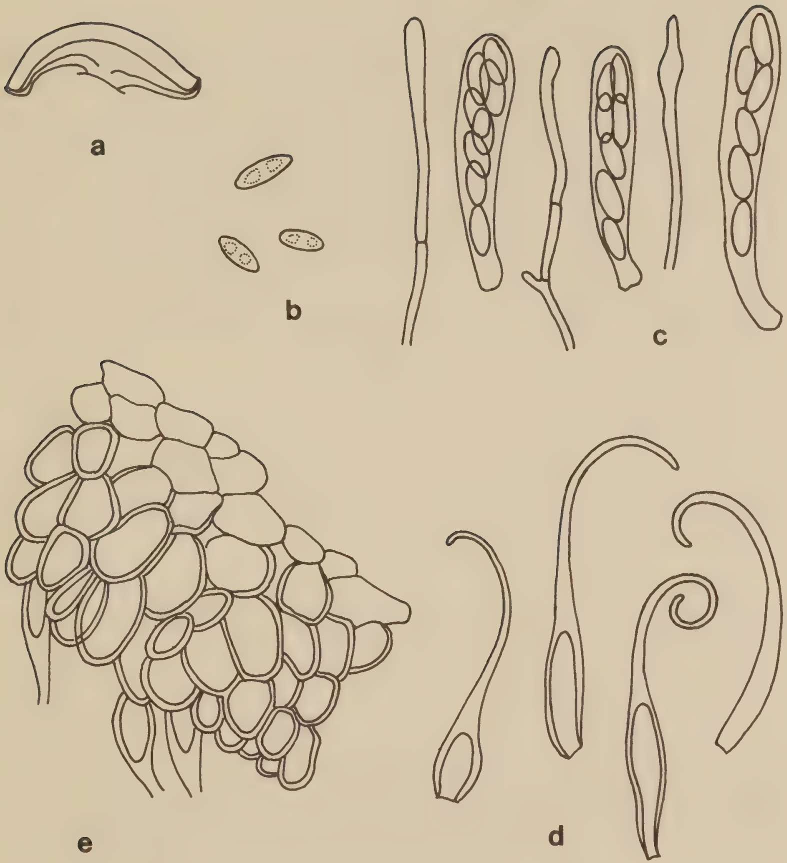


FIG. 7. *Unguiculariopsis acerina* (holotype): **a**. shape of apothecium, from top to bottom showing hymenium, medullary excipulum and ectal excipulum, **b**. ascospores, **c**. paraphysis apices and asci with ascospores, **d**. hairs, three with a solid apex and one with lumen at apex, **e**. structure of ectal excipulum; **a** x 50, **b**-**e** x 1300.

slightly swollen and sometimes deformed at apex, exceeding asci 3.5-5.0 µm, up to 2.3 µm wide.

HABITAT: Associated with a basidiomycete (Corticiaceae) on inner bark of *Acer rubrum* and of an unidentified tree.

HOLOTYPE: On inner bark of *Acer rubrum* on dead branch of a living tree, [associated with a corticiaceous fungus and a coelomycete], McLean, NY, United States, S. H. Strauss, 11. X. 1977, CUP 57020.

DISTRIBUTION: United States.

ILLUSTRATION: This paper, Fig. 7.

EXSICCATAE EXAMINED: None.

OTHER SPECIMEN EXAMINED: UNITED STATES: Associated with a corticiaceous basidiomycete on inner bark of an unidentified tree, Canton, Massachusetts, J. Zygglman, 3. I. 1988, FH.

Notes: The distinctions between this species and *Unguiculariopsis hamatopilosa*, the most similar fungus, are discussed in the notes for the latter. The distinctions between *U. acerina* and *U. adirondacensis* are indicated in the notes on the latter fungus. *U. acerina* differs from *U. robergei* in shorter and narrower ascospores, 8-spored asci, shorter hairs, dark and angular cells present in the medullary excipulum, and the strongly convex apothecia. Recently, Prof. Pfister kindly sent me an *Unguiculariopsis* associated with a corticiaceous fungus. My observation reveals that it is conspecific with the holotype *U. acerina* and that the host fungus of this species is a basidiomycete.

2. **Unguiculariopsis adirondacensis** Zhuang, **sp. nov.** (Fig. 8)

Ab U. acerina ascis constanter 8-sporis, pilis brevibus lumen ad apicem et non apicem solidum possidentibus, cellulis excipularibus minoribus, excipulo medulloso ex textura intricata et non varie ex textura angulari et intricata composito differens.

Apothecium cupulate to discoid, margin enrolled, sessile, 0.2-0.3(-0.4) mm in diam when fresh; hymenium vinaceous when fresh and dark vinaceous when dry; receptacle surface furfuraceous, light vinaceous when fresh and vinaceous when dry. Hairs distributed at margin and flanks, smooth-walled, with a swollen base and a fine, curved apex, light brown at base and pale yellow at apex, not becoming purple in Melzer's reagent with 10% KOH pretreatment, nonseptate, with lumen extending to the apex, 16-20 µm long. Ectal excipulum of textura angularis, 10-16 µm thick; cells brown, relatively thin-walled, isodiametric to ellipsoid, 4-8 µm in diam if isodiametric. Medullary excipulum of textura intricata, thin at margin and gradually thickened at base; hyphae subhyaline, light brown near ectal excipulum. Subhymenium indistinguishable. Asci 8-spored, clavate, J– in Melzer's reagent with 10% KOH pretreatment, (25-)27-35 x 4.5-5.0 µm, arising from croziers. Ascospores biseriate, ellipsoid, biguttulate, hyaline, 4.4-6.6 x 2.0-2.5 µm; spores shot 8 in a group, failing to germinate on PDA medium. Paraphyses filiform, septate near base, usually not exceeding asci, 1.5-2.0 µm wide.

HABITAT: On or associated with a *Lachnellula*-like discomycete.

HOLOTYPE: On or associated with a *Lachnellula*-like discomycete on *Abies balsamea*, Sagamore Road, Raquette Lake, NY, United States, J. H. Haines, 6. IX. 1986, CUP 61808.

DISTRIBUTION: United States.

ILLUSTRATION: This paper, Fig. 8.

EXSICCATAE EXAMINED: None.

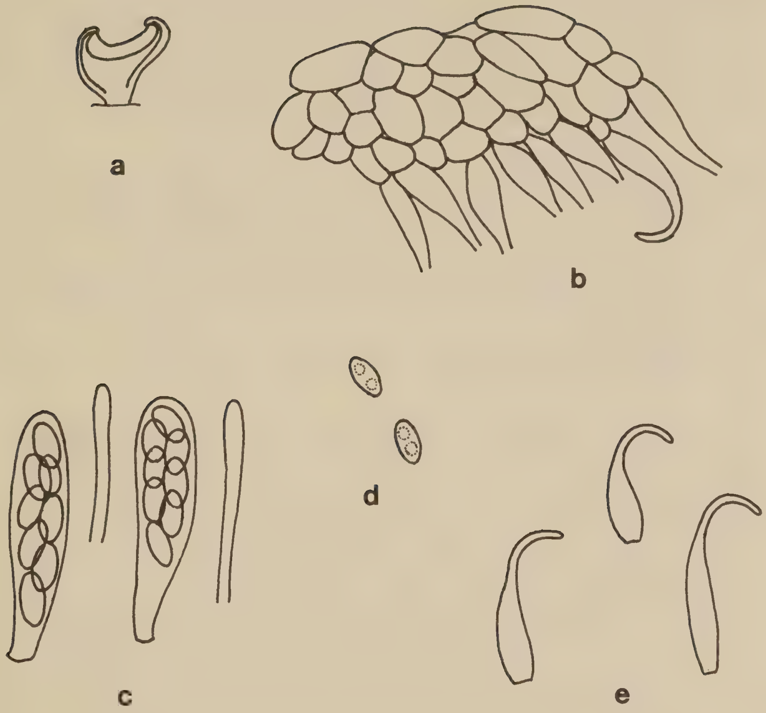


FIG. 8. *Unguiculariopsis adirondacensis* (holotype): **a**. shape of apothecium, from top to bottom showing hymenium, medullary excipulum and ectal excipulum, **b**. structure of ectal excipulum, **c**. paraphysis apices and asci with ascospores, **d**. ascospores, **e**. hairs with lumen at apex; **a** x 50, **b-e** x 1300.

OTHER SPECIMEN EXAMINED: None.

Notes: This is one of the very few species of *Unguiculariopsis* of which I have seen the fruit bodies in the fresh condition. The apothecia of this fungus are distributed among many apothecia of a *Lachnellula*-like discomycete; very few occur directly on apothecia of the host fungus. The number of the host ascocarps may be more than ten times that of its parasite. The colors of the hymenium and receptacle remain unchanged or are slightly darker after drying. Apothecia may be slightly deeper when dry than when they are fresh. The ascospores shot on potato dextrose agar medium were usually eight in a group and did not germinate.

Structurally, *U. adirondacensis* is somewhat similar to *U. robergei* subsp. *coelomyceticola*. It is different from that fungus in its small and 8-spored asci, small ascospores and ectal excipular cells, and short hairs which have a lumen extending to the apex instead of being solid at the apex. *U. adirondacensis* is similar to *U. acerina* in spore size and spore number per ascus, but it can be distinguished from *U. acerina* by the thinner-walled and smaller excipular cells, the medullary excipulum of textura intricata instead of textura angularis to textura intricata, the short hairs with a lumen extending to the apex, the consistently 8-spored asci instead of being 6- to 8-spored, and the host fungus.

3. **Unguiculariopsis australiensis** (Höhn.) Zhuang, **comb. nov.** (Fig. 9)

≡ *Encoeliella australiensis* Höhn., Sitzungsber. Kaiserl. Akad. Wiss., Math.-Naturwiss. Kl., Abt. 1. 119: 622, 1910.

≡ *Unguiculariopsis ilicincola* (Berk. & Br.) Rehm var. *australiensis* (Höhn.) Spooner, Bibl. Mycol. 116: 656, Fig. 135, 1987.

MISAPPLICATION:

Mollisiella ilicincola (Berk. & Br.) Mass., J. Linn. Soc. Bot. 31: 522, 1896 (pro parte).

Apothecium cupulate, margin enrolled, short stipitate, 0.4-0.7 mm in diam; hymenium vinaceous brown when dry and vinaceous when rehydrated; receptacle surface furfuraceous, grayish white when dry. Hairs scattered from margin to base of the apothecium, smooth-walled, with a wide base and a fine apex, pale brown at base and nearly hyaline at apex, hooked or slightly bent at apex, not becoming purplish in Melzer's reagent with 10% KOH pretreatment, nonseptate or occasionally with one septum near base, with lumen extending to the apex, 33-55 μm long. Ectal excipulum of textura angularis to textura globulosa, 15-47 μm thick, cells brown, somewhat thick-walled, ca. 5-14 μm in diam; receptacle surface with pustules. Medullary excipulum of textura intricata, 10-55 μm thick, the thickness varying from margin to base; hyphae subhyaline, parallel near ectal excipulum. Subhymenium indistinguishable. Asci 8-spored, cylindrical, J–, pore walls not turning blue in Melzer's reagent with 10% KOH pretreatment, 50-55 X 4.5-5.6 μm, with crozier at base. Ascospores uniseriate, spherical, guttulate, 3.1-3.7 μm in diam. Paraphyses filiform, septate, not or slightly deformed at apex, equal to or slightly exceeding asci, 2.0-2.2 μm wide.

HABITAT: On the fruit bodies of *Myriangium* sp.

HOLOTYPE EXAMINED: On *Myriangium* sp., Mount Macedon, Melbourne, Australia, B. M. Martin 460, IV. 18??, K-Hort. Bot. Reg. (isotype: FH-Höhnel Herb.) (all filed under *Encoeliella australiensis*).

DISTRIBUTION: Australia.

ILLUSTRATIONS: Spooner, B.M., Bibl. Mycol. 116: Fig. 135, 1987. This paper, Fig. 9.

EXSICCATAE EXAMINED: None.

OTHER SPECIMEN EXAMINED: None.

Notes: Massee (1896) had a very broad specific circumscription, and listed Martin 460, the type of *Unguiculariopsis australiensis*, together with the types of *Peziza hysterigena* and *P. ravenelii*, under the name of *Mollisiella ilicincola*. Höhnel (1910) separated *U. australiensis* (as

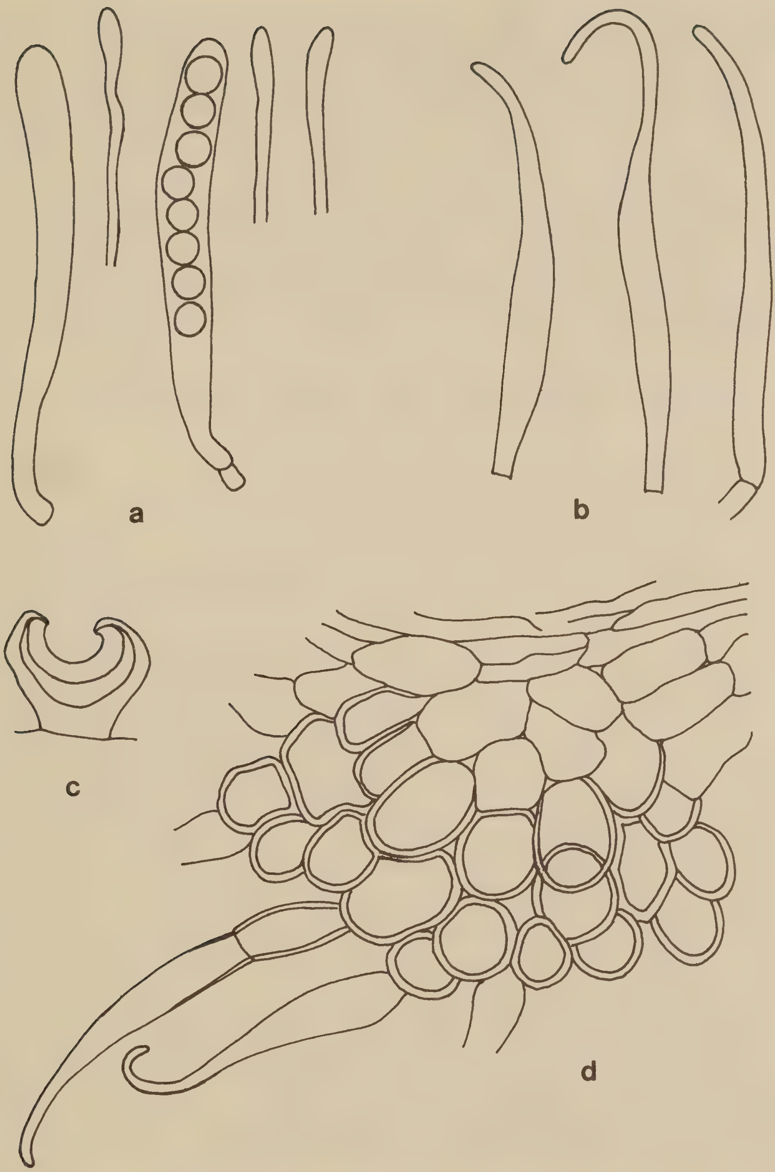


FIG. 9. *Unguiculariopsis australiensis* (holotype): **a**. paraphysis apices and asci with ascospores, **b**. hairs with lumen at apex, **c**. shape of apothecium, from top to bottom showing hymenium, medullary excipulum and ectal excipulum, **d**. structure of ectal excipulum; **a**, **b**, **d** x 1300, **c** x 50.

Encoeliella australiensis) from *M. ilicincola* by establishing the genus *Encoeliella*. As mentioned earlier in the history of taxonomy and nomenclature of *Unguiculariopsis*, *P. ravenelii*, the type species of the genus *Encoeliella*, is congeneric with *M. ilicincola*, the type species of *Unguiculariopsis*. *Encoeliella* becomes a later synonym of *Unguiculariopsis*.

Among the accepted species, *U. australiensis* and *U. ilicincola* are both on *Myriangium* species. Spooner (1987) treated *U. australiensis* as a variety of *U. ilicincola*. I feel that they are distinct sufficiently at the specific level. The former differs from the latter in its longer, gradually tapered and occasionally septate hairs, smaller and uniformly spherical ascospores, parallel hyphae in the medullary excipulum, and the pustulate receptacle.

4. **Unguiculariopsis dimorpha** (Seaver) Zhuang, **comb. nov.** (Fig. 10 a, b, c, d, e)

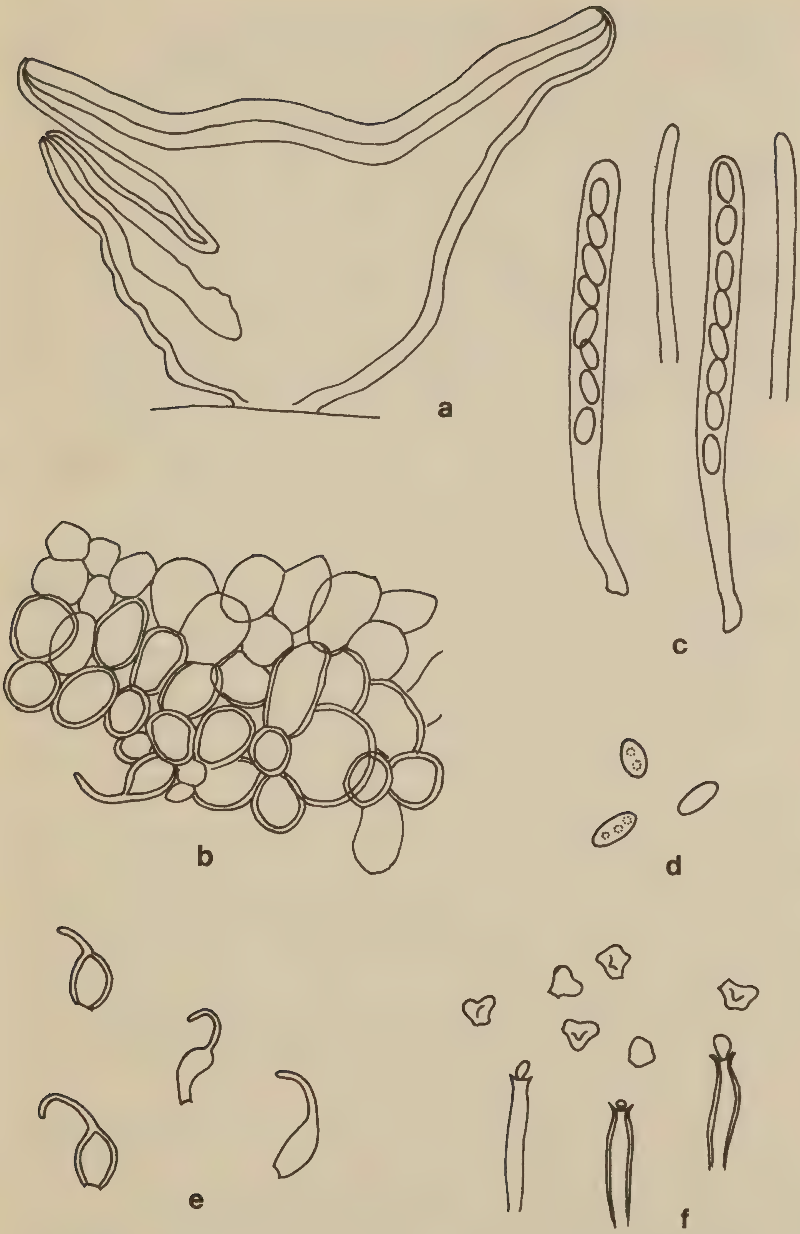
≡ *Dermatea dimorpha* Seaver, Mycologia 16: 8, Pl. 2, Figs. 1-4, 1924.

≡ *Cenangium dimorphum* (Seaver) Seaver, N. Am. Cup-Fung. p. 303, 1951.

= *Cenangium australe* Pat., Bull. Soc. Mycol. France 11: 219, 1895 [non *Cenangium australe* Speg., Bol. Acad. Nac. Ci. 11(2): 269, 1888].

Apothecium discoid at maturity, deeply cupulate when young, margin slightly enrolled, sessile, subsessile to shortly stipitate, up to 0.8-2.0(-2.5) mm in diam when dry; hymenium dark rosy, warm brown, reddish vinaceous (to dark vinaceous) when dry; receptacle surface slightly furfuraceous, cinnamon-brown when dry (with a purplish tint, hymenium slightly darker when fresh according the original description). Hairs mainly at margin and upper flanks, smooth-walled, with a swollen base and a fine, hooked apex, pale yellow at base, not becoming purplish in Melzer's reagent, nonseptate, 7-16(-18) µm long, marginal hairs with a lumen extending to the apex, others solid at apex. Ectal excipulum of textura angularis to textura globulosa, 18-36 µm thick, thicker near the base; cells brown, more or less thick-walled, isodiametric, ca. 4.5-13 µm in diam. Medullary excipulum of textura intricata; hyphae 3 µm wide, walls subhyaline. Subhymenium of textura intricata, not clearly differentiated. Asci 8-spored, cylindrical, J–, pore walls not turning blue in Melzer's reagent with or without KOH pretreatment, with croziers at base, ca. 48-55 x 4.0-4.5 µm (ca. 40 x 4 µm according to Seaver). Ascospores mostly uniseriate, ellipsoid, with 2(-3) guttules, 4.4-5.5 x 1.5-2.3 µm. Paraphyses filiform, septate, exceeding asci 0-6 µm, 1.5-2.0 µm wide.

FIG. 10. *Unguiculariopsis dimorpha* (holotype): **a**. shape of pycnidium and apotheium, from top to bottom showing hymenium, subhymenium, medullary excipulum and ectal excipulum, **b**. structure of ectal excipulum, **c**. paraphysis apices and asci with ascospores, **d**. ascospores, **e**. hairs, two with a solid apex and two with lumen at apex, **f**. conidia and conidiogenous cells; **a** x 50, **b-e** x 1300, **f** x 1580.


a
b
c
d
e
f

ANAMORPH: *Deltosperma dimorphum*.

HABITAT: On beaked pyrenomycetes (?diatrypaceous).

HOLOTYPE EXAMINED: [On a beaked pyrenomycete] on dead branches of an unidentified plant, St. Thomas #780, United States, F. J. Seaver, 11. III. 1923, NY (as *Dermatea dimorpha*).

DISTRIBUTION: Bolivia, Brazil, Ecuador, Puerto Rico, United States, Venezuela.

ILLUSTRATIONS: Seaver, F.J., Mycologia 16: Pl. 2, Figs. 1-4, 1924. This paper, Fig. 10.

EXSICCATAE EXAMINED: RICK, FUNGI AUSTRO-AMERICANI: On stromata of a pyrenomycete, São Leopoldo, Brazil, Rick 147, 1905, BPI, BPI-Weir 20739, FH-General Herb., FH-Patouillard Herb. (filed under *Cenangium episphaerium*), NY (filed under *Cenangium dimorphum*).

OTHER SPECIMENS EXAMINED: BOLIVIA: on wood (pyrenomycete associated), at 1550 m, Rio Llolosa, Prov. Nor-Yungos, Dept. La Paz, R. Singer, 31. I. 1956, K-B791 (filed under *Encoelia infundibuliformis*).

BRAZIL: [On fruit bodies of a long-beaked pyrenomycete], S. Leopoldo, Rio Grande do Sul., Rick, 1907, BPI-Theissen, Dec. Fung. Brazil 267 (filed under *Cenangium episphaerium*); [on fruit bodies of a long-beaked species of Diatrypaceae], Santa Maria, Rio Grande do Sul., Rick, 1935, FH-Rick Exped. Brazil (filed under *Cenangium episphaerium*); on a long-beaked species of Diatrypaceae (as *Eutypa comosa* Speg.), Sao Leopoldo, Rio Grande do Sul, Rick, (no date), FH-Rick Exped. Brazil (filed under *Cenangium episphaerium*).

ECUADOR: On decorticated wood [associated with a long-beaked species of Diatrypaceae], San Jorge, (no collector), VII. 1892, FH-Patouillard Herb. (holotype of *Cenangium australe*) (filed under *Cenangium australe*).

PUERTO RICO: [On a beaked pyrenomycete] on branches of an unidentified plant, Martin Pena, J. G. Stevensen, 22. II. 1914, NY (filed under *Cenangium dimorphum*).

UNITED STATES: On wood of an unidentified plant [associated with a long-beaked pyrenomycete], near John Brewer's Bay, St. Thomas #795, F. J. Seaver, 12. III. 1923, NY (as *Dermatea dimorpha*).

VENEZUELA: On bark of dead *Citrus* with moss, coffee plantations, near San Cristobal, alt. 900-1000 m, Chardon, 19 IX. 1932, NY (as *Dermatea dimorpha*).

Notes: This species is, in some ways, similar to *U. infundibuliformis*. But *U. dimorpha* differs from *U. infundibuliformis* in having small and sessile to substipitate instead of large and long-stipitate apothecia, shorter pycnidia, and shorter and wider conidia.

The apothecia and pycnidia of specimens collected from St. Thomas, USA and from Puerto Rico are slightly smaller than those from Brazil, Ecuador and Venezuela. The host fungus of the holotype and of the collection from Puerto Rico is a pyrenomycete with beaked perithecia that grow solitary on the plant substrate. The other specimens examined are on a pyrenomycete with long-beaked, gregarious perithecia. The collections from Brazil have somewhat elongated excipular cells in comparison with isodiametric cells of those from the other areas. The type of *C. australe* may differ slightly from that of *U. dimorpha*. But I do not distinguish them at specific level.

Some of the specimens examined were misidentified as *Cenangium episphaerium* Schw. I examined the type of *C. episphaerium*. My observations indicate that *C. episphaerium* is also fungicolous, but on a different host fungus, and is morphologically distinct from *U. dimorpha*.

The anamorphs of *U. dimorpha*, *U. infundibuliformis* and *U. parasitica* are similar to the species of *Trigonosporium* in conidial shape, but the anamorphs of *Unguiculariopsis* differ significantly from *Trigonosporium* in shape and size of pycnidia (elongated with beak *vs.* globose; 0.3-1.5 x 0.15-0.35 mm *vs.* 0.08-0.25 mm in diam.), pale brown *vs.* hyaline conidia (Sutton, 1971), fungicolous habit, and the connection with *Unguiculariopsis* teleomorphs. A new genus is proposed and described here based on the anamorphs of *Unguiculariopsis*.

Deltosperma Zhuang, **gen. nov.**

Pycnidia superficialia, gregaria, varie breviter vel elongate conica, vel subcylindrica, cinnamomea vel atrobrunnea, pariete pycnidiali ex stratis duobus formato, strato exteriore ex cellulis brunneis angularibus (textura angulari), strato interiore ex hyphis intertextis (textura intricata) formato; conidiophora absentia vel difficulter ab parietis pycnidialis strato interiore distinguibilia; cellulae conidiogenae enteroblasticae, monophialidicae, vel annelidicae, varie elongate lageniformes vel subcylindricae, pallide vel dilute brunneae, parietibus laevibus praeditae; conidia varie deltoidea vel irregulariter angularia, nodulosa, pallide brunnea, unicellularia, parietibus tenuibus et laevibus praedita; cum fungis consociatum.

Pycnidia superficial, gregarious, short to elongate conical, or subcylindrical, cinnamon brown to dark brown. Pycnidial wall with two layers, outer layer with brown, angular cells (textura angularis), inner layer with interwoven hyphae (textura intricata). Conidiophores absent or difficult to distinguish from inner layer of the pycnidial wall. Conidiogenous cells enteroblastic, phialidic, elongate-lageniform to subcylindrical, with smooth, pale brown to brown walls. Conidia deltoid to irregularly angular, nodulose, unicellular, with pale brown, thin and smooth walls; on or associated with other fungi. Anamorphs of *Unguiculariopsis* species.

Type: *Deltosperma infundibuliformis*.

Deltosperma dimorphum Zhuang, **sp. nov.** (Fig. 10 a, f)

Ab D. infundibuliformi pycnidiis brevioribus et angustioribus, cellulis conidiogenis parum longioribus et latioribus, brunneis et parietibus crassis praeditis, conidiis latioribus, et consocietate cum teleomorpha Unguiculariopside dimorphae differens.

Pycnidia arising separately or together with and often fused to the base of apothecia, superficial, gregarious, elongated conical, to flask-shaped, cinnamon-brown to reddish brown, 0.7-0.9(-1.2) x 0.15-0.2 mm. Structure of pycnidial wall similar to that of apothecial excipulum, outer layer of textura angularis, cells brown, somewhat glassy and thick-walled; inner layer hyphae light brown, slightly interwoven, more or less parallel to the outer surface. Conidiophores short, scarcely distinguishable from cells of the pycnidial inner layer. Conidiogenous cells phialidic, elongate-lageniform to nearly cylindrical, light brown, smooth-walled, many of them with dark brown and thick-walls near the upper portion, protruding into the pycnidial cavity, some with a wide collarette, 11-14.5 x 2.0-3.0 µm. Conidia irregularly angular to deltoid, nodulose, pale brown, unicellular, uniguttulate, 2.5-3.0 x 3.0 µm (2 µm in diam according to Seaver).

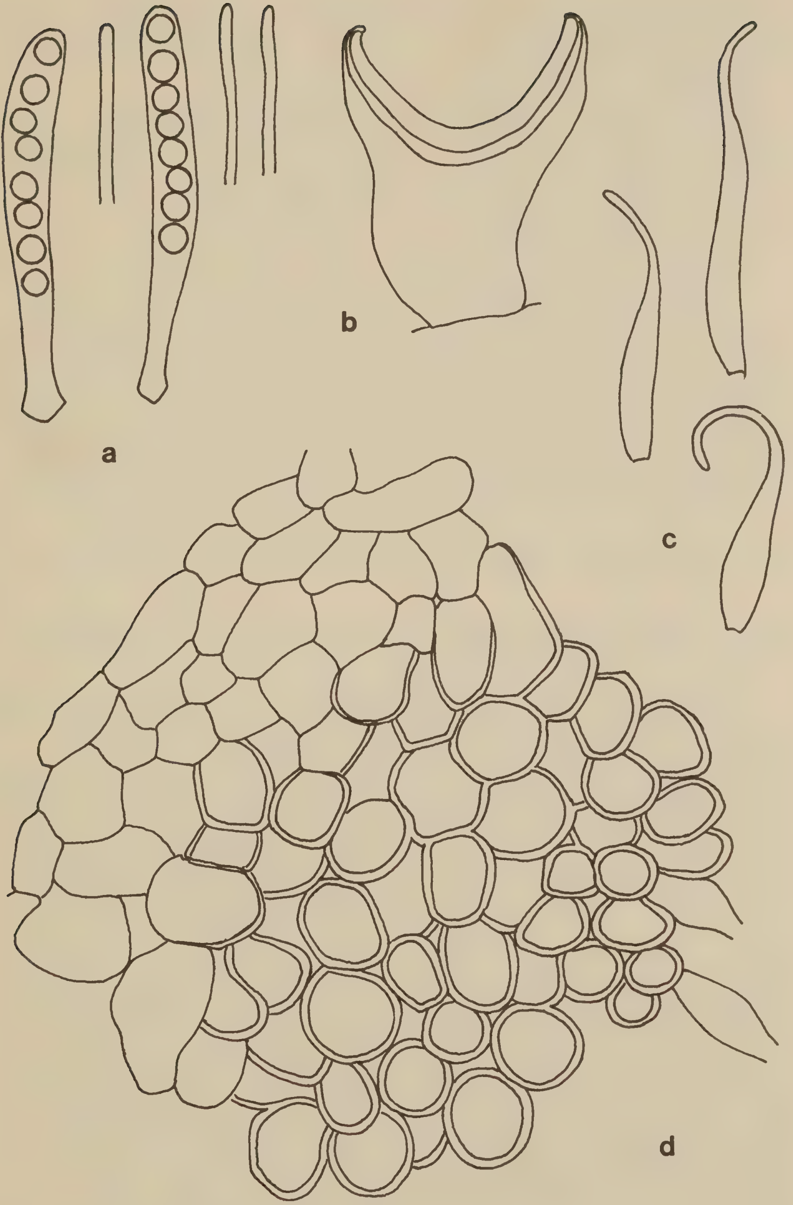
HOLOTYPE: [On a beaked pyrenomycete] on dead branches of an unidentified plant, St. Thomas #780, F. J. Seaver, 11. III. 1923, NY.

5. **Unguiculariopsis godroniicola** Zhuang, **sp. nov.** (Fig. 11)

Ab speciebus aliis Unguiculariopsidis apothecio late stipitato, stipite pubescente, cellulis varie angularibus vel globosis in excipulo ectali ab margine per latera ad basem totam et apothecii stipitem extensis differens; speciei U. ravenelii artissime affinis, sed ascosporis minoribus, pilis longioribus, excipulo medulloso multo tenuiore et subhymenio absente differens.

Apothecium cupulate, somewhat unequal-sided, margin enrolled, broadly stipitate, 0.4-0.8 mm in diam when dry and less than 1.3 mm when rehydrated; hymenium dark to vinaceous brown when dry; receptacle vinaceous brown, lighter than hymenium, surface furfuraceous. Hairs occurring at margin and upper flanks, with a swollen base and a fine, hooked apex, walls pale brown, very faintly purple in Melzer's reagent after 10% KOH pretreatment, usually nonseptate, with lumen extending to the apex, ca. 20-44 µm long. Stipe covered with hyaline hyphae. Ectal excipulum of textura globulosa to textura angularis, thick at flanks and base, occupying most of the excipular tissues and extending to the stipe; cells dark brown to brown, thick-walled in the outer layers and becoming thinner toward inside, isodiametric to ovoid, ca. 4.5-12.5 µm in diam. Medullary excipulum of textura intricata, 20-35 µm thick; hyphae subhyaline, loosely interwoven. Subhymenium indistinguishable. Asci 8-spored, subcylindrical, to subfusoid, J–, pore walls not turning blue in Melzer's reagent with 10% KOH pretreatment, ca. 47-55 x 4.2-4.8 µm,

FIG. 11. *Unguiculariopsis godroniicola* (holotype): **a**. paraphysis apices and asci with ascospores, **b**. shape of apothecium, from top to bottom showing hymenium, medullary excipulum and ectal excipulum, **c**. hairs with lumen at apex, **d**. structure of ectal excipulum; **a, c, d** x 1300, **b** x 50.


a
b
c
d

with crozier at base. Ascospores uniseriate, spherical, uniguttulate, ca. 2.9-3.0 μm in diam. Paraphyses filiform, 1-2 septate, not exceeding asci, 1.5 μm wide.

HABITAT: On apothecia of *Godronia confertus*.

HOLOTYPE: On *Godronia confertus* (Hone) Groves (as *Godronia confertatus* Hone) on *Prunus cerasus*, Payolle, 1100 m alt., Hautes Pyrénées (Campan), France, F. Candoussau, 6. V. 1973, ZT (isotypes: CUP 61668; Pers. Herb. F. Candoussau 4372).

DISTRIBUTION: France.

ILLUSTRATION: This paper, Fig. 11.

EXSICCATAE EXAMINED: None.

OTHER SPECIMEN EXAMINED: None.

Notes: This species is distinct from other species of *Unguiculariopsis* in the unequal-sided, broadly stipitate apothecium, hairy stipe, and angular to globose cells in the ectal excipulum which extend from the margin through the flanks to the base and stipe of the apothecium. *U. ravenelii* seems similar to this species in the apothecial shape. But *U. godroniicola* differs from *U. ravenelii* in thin medullary excipulum, lack of subhymenium, and smaller ascospores. The host fungus of the former is a *Godronia* species, while the latter is a *Rhytidhysteron* species.

6. **Unguiculariopsis hamatopilosa** (Graddon) Zhuang, **comb. nov.** (Fig. 12)

≡ *Unguicularia hamatopilosa* Graddon, Trans. Brit. Mycol. Soc. 87: 333, Fig. 8, 1986.

Apothecium discoid to flat with an undulate margin when dry and convex when rehydrated, sessile with apothecial base inserted into the substrate, 0.3-0.5 mm in diam; hymenium warm brown when dry; receptacle surface furfuraceous, whitish brown when dry. Hairs scattered from margin to the base of apothecium, smooth-walled, with a swollen base and a fine, hooked to coiled apex, walls pale yellow, not becoming purple in Melzer's reagent with 10% KOH pretreatment, nonseptate, with a solid apex, 22-30 μm long. Ectal excipulum of textura angularis, very thin at margin, 7.5-18.5 μm thick at flanks; cells brown, somewhat thick-walled, isodiametric to ellipsoid, if isodiametric ca. 5-9 μm in diam. Medullary excipulum of textura angularis to textura intricata, very thin; hyphae somewhat parallel at flanks near margin, becoming angular near and at base, walls brown. Subhymenium indistinguishable. Asci 2- to 4-spored, clavate, J–, pore walls not turning blue in Melzer's reagent with 10% KOH pretreatment, 20.5-25 x 3.8-4.8 μm (30 x 5 μm according to the original author), arising from croziers. Ascospores uniseriate to biseriate, ellipsoid, biguttulate, subhyaline, 4.8-8.0 x 2.0-2.5 μm. Paraphyses filiform, 1-septate near base, often unbranched, not or slightly exceeding asci, 1.7-2.2 μm wide.

HABITAT: On fruit bodies of *Didymosphaeria ?oblitescens* on stem of *Rubus fruticosus*.

HOLOTYPE EXAMINED: None.

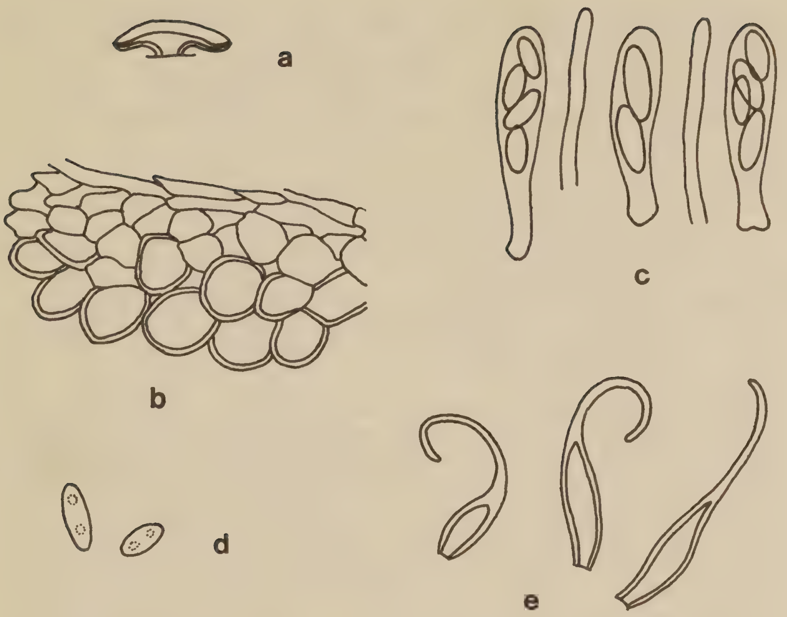


FIG. 12. *Unguiculariopsis hamatopilosa* (W.D.G. 4286A): **a**. shape of apothecium, from top to bottom showing hymenium, medullary excipulum and ectal excipulum, **b**. structure of ectal excipulum, **c**. paraphysis apices and asci with ascospores, **d**. ascospores, **e**. hairs with a solid apex; **a** x 50, **b**, **c**, **d**, **e** x 1300.

AUTHENTIC SPECIMEN EXAMINED: [On fruit bodies of *Didymosphaeria ?oblitescens*] on *Rubus fruticosus* stem, Chillington, Devon, England, XII. 1986, Pers. Herb. W.D.Graddon 4286A (filed under *Unguicularia hamatopilosa*).

DISTRIBUTION: England.

ILLUSTRATIONS: Graddon, W. D., Trans. Brit. Mycol. Soc. 87: 333, Fig. 8. This paper, Fig. 12.

EXSICCATAE EXAMINED: None.

OTHER SPECIMENS EXAMINED: None.

Notes: Anatomically, this fungus is similar to *U. acerina* of North America, but it is obviously a distinct species and on a different host fungus. These two species can easily be separated from each other by their spore number per ascus and the sizes of asci, of ascospores and of excipular cells. Since the holotype of this species is very scanty, Dr. Graddon sent me another collection which he treated as a representative of this species, and was collected from the same *Rubus* in the same area exactly a year later. Though I did not examine the holotype, W.D.G. 4286A matches the original description (Graddon, 1986) quite well, and is authentic.

Graddon failed to note the association with *Didymosphaeria.*

7. **Unguiculariopsis hysterigena** (Berk. & Br.) Korf, Phytologia 21: 207, 1971. (Fig. 13)

≡ *Peziza hysterigena* Berk. & Br., J. Linn. Soc. 14: 106, 1873.

≡ *Lachnellula hysterigena* (Berk. & Br.) Sacc., Syll. Fung. 8: 391, 1889.

MISAPPLICATIONS:

Mollisiella ilicincola (Berk. & Br.) Mass., J. Linn. Soc. Bot. 31: 522, 1896 (pro parte).

Unguiculariopsis ilicincola (Berk. & Br.) Rehm, Ann. Mycol. 7: 400, 1909 (pro parte).

Encoeliella ravenelii (Berk. & Curt.) Höhn., Sitzungsber. Kaiser. Akad. Wiss., Math.-Naturwiss. Kl., Abt. l. 119: 619, 1910 (pro parte), (nom. superfl., Art. 63.1, ICBN).

Apothecium discoid to cupulate, margin enrolled, sessile, up to 1 mm in diam; hymenium vinaceous brown; receptacle grayish brown when dry, darker brown when rehydrated (hymenium grayish, receptacle whitish when fresh according to Berkeley and Broome), receptacle surface furfuraceous. Hairs occurring at the margin and upper flanks of apothecium, very thick-walled, with a swollen base and a fine, hooked apex, light brown at base and subhyaline at apex, becoming strongly purple in Melzer's reagent with 10% KOH pretreatment, surface of hairs and some cells granulate, granules rather coarse, hyaline, and dissolving rapidly in KOH and slowly in cotton blue lactic acid, nonseptate, with lumen extending to the apex, ca. 16-22 µm long. Ectal excipulum of textura globulosa to textura angularis, 25-55 µm thick; cells brown to subhyaline, very thick-walled, isodiametric, ca. 6-12 µm in diam, outermost cells sometimes loosening. Medullary excipulum of textura intricata; hyphal walls light brown. Subhymenium indistinguishable, or occasionally present. Asci 8-spored, cylindrical, J–, pore walls not turning blue in Melzer's reagent with 10% KOH pretreatment, 35-44 x 4.8-5.9 µm, arising from croziers. Ascospores irregularly biseriate in youth, uniseriate at maturity, spherical, 3.3-4.6 µm in diam. Paraphyses filiform, 0-1 septate, exceeding asci by up to 7 µm, deformed or slightly tapered towards the apex, 1.2-1.5 µm wide.

HABITAT: On hymenium of *Rhytidhysteron rufulum*.

HOLOTYPE EXAMINED: On *Rhytidhysteron rufulum*, Central province, Ceylon, Thwaites 1067, XII. 1868, K-Broome Herb. (as *Peziza hysterigena*) (isotype: FH-Höhnel Herb., filed under *Mollisiella ilicincola*).

DISTRIBUTION: China, Sri Lanka.

ILLUSTRATIONS: ?Massee, G., J. Linn. Soc. 31: Pl. 18, Figs. 15-18 (*Mollisiella ilicincola*). This paper, Fig. 13.

EXSICCATAE EXAMINED: None.

OTHER SPECIMENS EXAMINED: CHINA: On *R. rufulum*, Ling-shui, Hainan, S. Q. Deng 8299, 5. I. 1934, BPI (filed under *Tryblidiella rufula*); on *R. rufulum*, Ling-shui, Hainan, S. Q. Deng 834, 3. IV. 1934, CUP-CH 259, HMAS 45100 (filed under *Tryblidiella rufula*); on

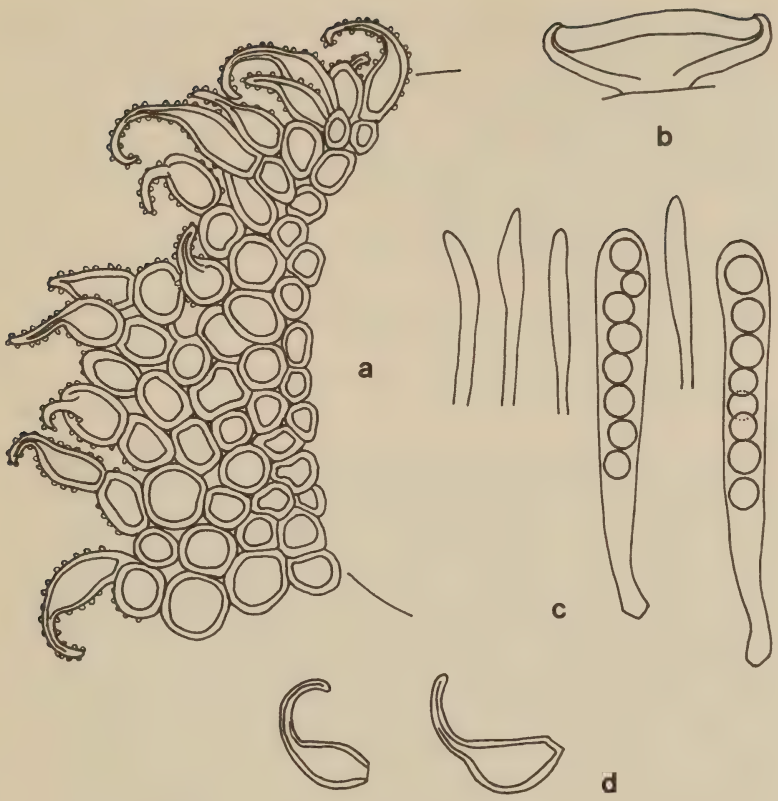


FIG. 13. *Unguiculariopsis hysterigena* (holotype): **a**. structure of ectal excipulum at margin and flank, with granulate hairs, **b**. shape of apothecium, from top to bottom showing hymenium, medullary excipulum and ectal excipulum,**c**. paraphysis apices and asci with ascospores, **d**. smooth-walled hairs after KOH treatment; **a**, **c**, **d** x 1300, **b** x 50.

R. rufulum, Ling-shui, Hainan, S. Q. Deng 2219, 23. IV. 1934, CUP-CH 857 (filed under *Tryblidiella rufula*).

Notes: Höhnel (1910) synonymized this species with *Unguiculariopsis ravenelii* and treated *U. ravenelii* as a slightly aberrant form of *U. hysterigena*. Although both species occur on *Rhytidhysteron rufulum*, type studies have revealed that they are distinct taxa. The loosely interconnected and very thick-walled excipular cells, presence of granules on the hair surface and on the outermost excipular cells that dissolve in KOH, distribution of hairs on the receptacle surface only at margin and the upper flanks, and larger ascospores are significant characteristics to distinguish *U. hysterigena* from *U. ravenelii*.

8. **Unguiculariopsis ilicincola** (Berk. & Br.) Rehm, Ann. Mycol. 7: 400, 1909. (Fig. 14)

≡ *Peziza ilicincola* Berk. & Br., Ann. Mag. Nat. Hist. Ser. 3, 7: 450, pl. XVI, Fig. 17, 1861.

≡ *Mollisia ilicincola* (Berk. & Br.) Phill., Brit. Disc. p. 193, 1887.

≡ *Pseudohelotium ilicincola* (Berk. & Br.) Sacc. (ut '*ilicincolum*', Syll. Fung. 8: 304, 1889.

≡ *Mollisiella ilicincola* (Berk. & Br.) Mass., Brit. Fung.-Fl. 4: 222, Fig., 1895.

≡ *Pithyella ilicincola* (Berk. & Br.) Boud., Hist. Classif. Disc. Eur. p. 125, 1907.

≡ *Hyalopeziza ilicincola* (Berk. & Br.) Korf & Kohn, Mycotaxon 10: 509, 1980.

Apothecium cupulate to discoid, margin enrolled, sessile to subsessile, less than 1 mm in diam; hymenium dark brown when dry (when fresh cinereous tinged with rose according to Berkeley and Broome; pale brown, purple, rosy cinereous according to Phillips); receptacle surface furfuraceous, grayish white when dry (dirty white when fresh according to Berkeley, Broome and Phillips). Hairs scattered from margin to base of apothecium; smooth-walled, with a swollen base and a fine, hooked apex, pale brown at base, not purple in Melzer's reagent with 10% KOH pretreatment, nonseptate, with lumen extending to the apex, (15-)20-33(-37) µm long. Ectal excipulum of textura angularis to textura globulosa, 15-25 µm thick; cells brown, slightly thick-walled, ca. 6-14 µm in diam. Medullary excipulum of textura intricata; hyphal walls light brown. Subhymenium indistinguishable. Asci 8-spored, cylindrical, J–, pore walls not turning blue in Melzer's reagent with 10% KOH pretreatment, ca. 50-58 x 4.7-6.6 µm. Ascospores uniseriate, subspherical to spherical, uniguttulate, 3.4-5.3(-6.0) µm in diam, or 3.9-4.5(-6.0) x 3.7-4.3 µm. Paraphyses filiform, septate, branched, deformed at apex, not exceeding asci, less than 2 µm wide.

HABITAT: On *Myriangium* spp.

HOLOTYPE EXAMINED: On *Myriangium* sp. on holly, Chiselhirst, Kent, England, M. J. Berkeley, XI. 1859, K-Hort. Bot. Reg. (as *Peziza ilicincola*).

DISTRIBUTION: England, France, Italy.

ILLUSTRATIONS: Berkeley, M.J. and C.E. Broome, Ann. Mag, Nat. Hist. Ser. 3, 7: Pl. XVI, Fig. 17, 1861 (*Peziza ilicincola*). Massee, G., Brit. Fung.-Fl. 4: 222, Fig., 1895 (*Mollisiella ilicincola*). Dennis, R.W.G., Brit. Ascom. Fig. 20B, 1968 (1st. ed.), 1978 (2nd. ed.) (*Pithyella ilicincola*). This paper, Fig. 14.

EXSICCATAE EXAMINED: None.

OTHER SPECIMENS EXAMINED: ENGLAND: [On substrate with *Myriangium* sp.], R.W.J. Keith, XII. 1844, K-Phillips (as *Peziza ilicincola*).

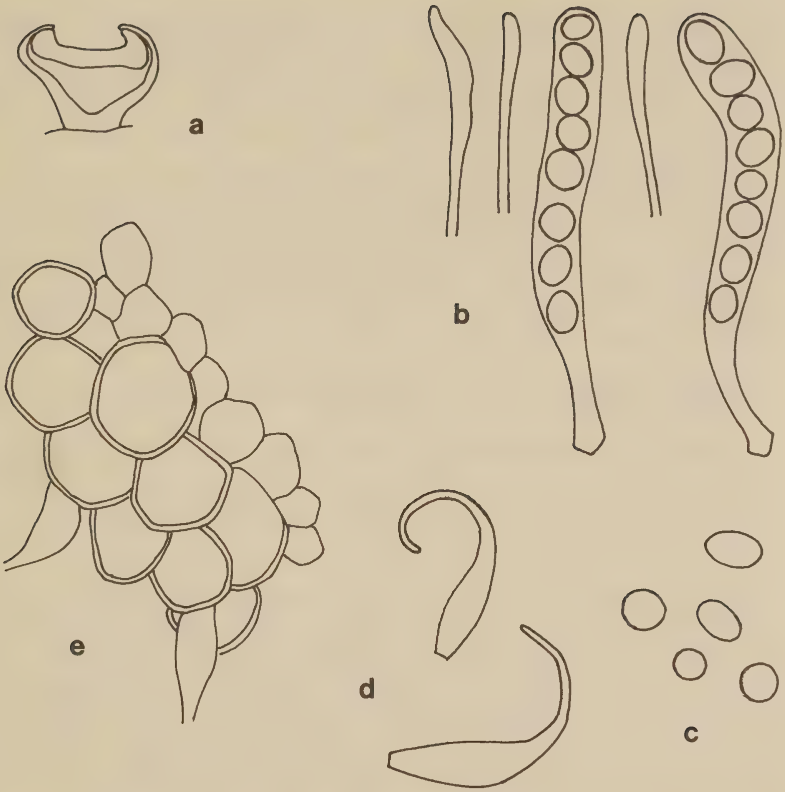


FIG. 14. *Unguiculariopsis ilicincola* (holotype): **a**. shape of apothecium, from top to bottom showing hymenium, medullary excipulum and ectal excipulum, **b**. paraphysis apices and asci with ascospores, **c**. ascospores, **d**. hairs with lumen at apex, **e**. structure of ectal excipulum; **a** x 50, **b-e** x 1300.

FRANCE: On *Myriangium duriae* on *Acer opalus*, forest of St. Lambert, Vaucluse, E. Müller, 25. V. 1962, ZT (filed under *Pithyella ilicincola*).

ITALY: On *Myriangium* sp., Naples, (no collector), II. 1878, K-Phillips (Nom. nud.: labelled as *Peziza myriangii* Ces.); on *Myriangium* sp. on holly bark, (no collector), (no date) purchased from the Herbarium of G. Massee in 1909, NY (filed under *Mollisiella ilicincola*).

Notes: This is the type species of *Unguiculariopsis*. Boudier (1907), Moser (1963), and Dennis (1978) put this species under the genus *Pithyella*, which is typified by *P. hypnina* (Boudier, 1885), a fungus that grows on moss (Boudier, 1905-1911; Quélet, 1879, 1881), which obviously differs from the type of *Unguiculariopsis* (Korf & Zhuang, 1987).

Morphologically, *U. ilicincola* can be separated from its closest relative, *U. ravenelii*, by the smaller apothecia, longer hairs which do not become strongly purple in Melzer's reagent, larger excipular cells, lack of subhymenium, and the presence of subspherical and larger ascospores. Saccardo (1889), Höhnel (1910), and Korf (1971, 1973), correctly distinguished the two species. This study agrees with their specific concept.

Massee (1896) provided an illustration under the name *Mollisiella ilicincola* when he synonymized *Peziza hysterigena* and *P. ravenelii* with *P. ilicincola*. But what he drew was definitely not from the type of *U. ilicincola*. It may be from either *U. hysterigena* or *U. ravenelii*, probably the latter. Seaver (1939, 1951) had the same taxonomic opinion and illustrated *U. ravenelii* under the name *M. ilicincola*. Their illustrations cannot represent *U. ilicincola*.

9. **Unguiculariopsis infundibuliformis** (Durand) Korf, Phytologia 21: 207, 1971. (Fig. 15)

≡ *Midotis infundibuliformis* Durand, Proc. Am. Acad. Arts Sci. 59: 7, Pl. II, Figs. 2-4, 1923.

≡ *Encoelia infundibuliformis* (Durand) Dennis, Kew Bull. 1954: 334, Fig. 43, 1954.

Apothecium discoid, unequally sided, margin undulate, not obviously enrolled, long-stipitate, up to 4 mm in diam; hymenium wine red (young) to brown (mature) when dry; receptacle surface roughened and furfuraceous at margin, cinnamon-brown when dry (hymenium grey or brownish grey, receptacle cinnamon-brown when fresh according to Durand). Hairs mainly at margin and flanks near margin, smooth-walled, with a swollen base and a fine, hooked apex, brown at base, not becoming purplish in Melzer's reagent with 10% KOH pretreatment, nonseptate, (12-)14-23 μm long, with lumen extending to the apex. Ectal excipulum of textura angularis to textura globulosa, 25-50(-75) μm thick; cells brown, thick-walled, subspherical at base and ellipsoid near margin, ca. 5-17(-22) μm in diam, the axes of cells perpendicular to the outer surface. Medullary excipulum of textura intricata; hyphae somewhat parallel to the outer surface, hyphal walls subhyaline to light brown. Subhymenium of textura intricata, 25-80 μm thick. Asci 8-spored, cylindrical, J–, pore walls not turning blue in Melzer's reagent with or without KOH pretreatment, 44-51 x 3.7-4.4 μm. Ascospores uniseriate, ellipsoid, with 2-3 guttules, 3.7-5.7(-6.0) x 1.4-2.2 μm. Paraphyses filiform, slightly deformed at apex, exceeding asci 0-6 μm, ca. 1.5 μm wide.

ANAMORPH: *Deltosperma infundibuliformis*.

HABITAT: Associated with a species of the Diatrypaceae (with gregarious perithecia) on rotting log.

HOLOTYPE EXAMINED: [On fruit bodies of a long-beaked species of Diatrypaceae or associated with the fungus], Emperor Valley, Port of Spain, Trinidad, R. Thaxter 4126, XII. 1912, FH-General Herb. (isotype: CUP-D 10763 (15-29) (all filed under *Midotis infundibuliformis*).

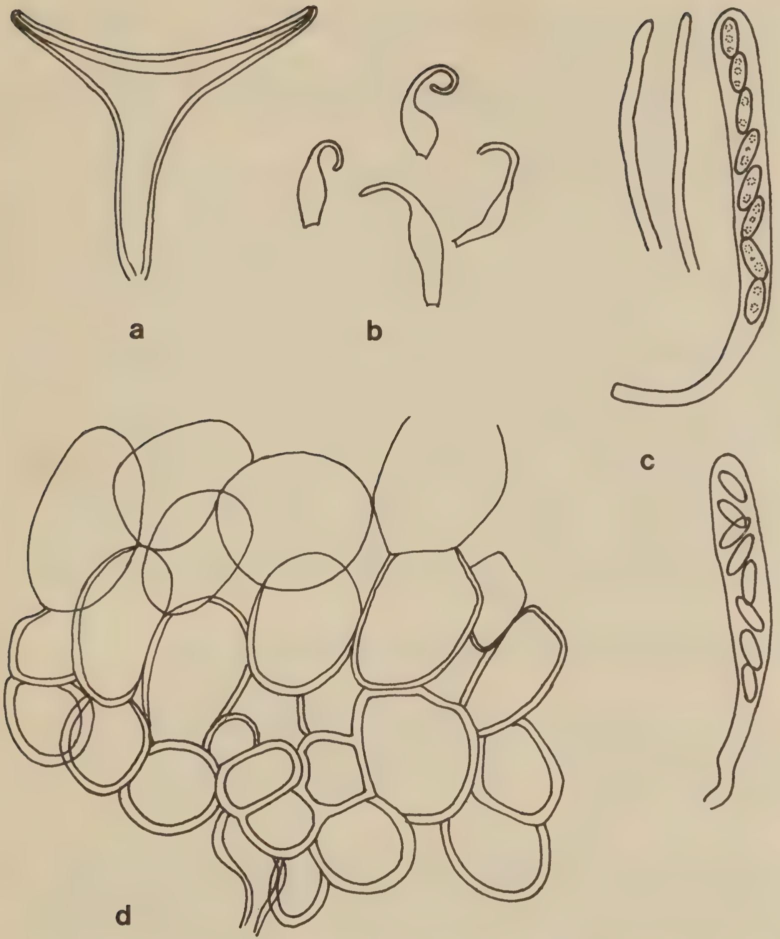


FIG. 15. *Unguiculariopsis infundibuliformis* (holotype): **a**. shape of apothecium, from top to bottom showing hymenium, medullary excipulum andectal excipulum, **b**. hairs with lumen at apex, **c**. paraphysis apices and asci with ascospores, **d**. structure of ectal excipulum; **a** x 9.5, **b-d** x 1300.

DISTRIBUTION: Philippines, Trinidad.

ILLUSTRATIONS: Durand, E.J., Proc. Amer. Acad. Arts Sci. 59: 19, Pl. 11, Figs. 2-4, 1923 (*Midotis infundibuliformis*). Dennis, R. W. G., Kew Bull. 1954: 334, Fig. 43, 1954; Kew Bull. Add. Ser. 3, Fig. 7K, 1970. This paper, Fig. 15, 16.

EXSICCATAE EXAMINED: None.

OTHER SPECIMENS EXAMINED: PHILIPPINES: on wood [associated with a long-beaked species of Diatrypaceae], Los Baños, C. F. Baker, (no date), FH-General Herb., Thaxter 4128 (filed under *Midotis infundibuliiormis*).

TRINIDAD: On a long-beaked species of Diatrypaceae, marked on the label "Type gathering of *Midotis infundibuliformis* Durand," Emperor Valley, R. Thaxter (as 4126), I. 1913, FH-General Herb., NY (filed under *Midotis infundibuliformis*).

Notes: This fungus was correctly recognized and transferred to *Unguiculariopsis* by Korf (1971), in spite of its extremely large and long-stipitate apothecia. *U. infundibuliformis* shares the common features with other members of the genus in structure of apothecium, shape of hairs, and habitat. When Durand (1923) described the species, he did not notice the association between this fungus and another ascomycete on the same substrate. Korf and Kohn (1980) clearly pointed out that species of *Unguiculariopsis* occur on fungi. During my study, this concept has been firmly established: almost all species of *Unguiculariopsis* are fungicolous. The host fungus of this species is a diatrypaceous ascomycete that has black, long-beaked perithecia, J+ asci, and allantoid ascospores.

The distinctions between *U. infundibuliformis* and *U. dimorpha* have previously been indicated, and those between *U. infundibuliformis* and *U. parasitica* will be discussed in the notes for the latter species. The presence of the anamorph had been noticed, and its morphology was well-described and illustrated by Durand (1923) without naming it. I treat it here as a new species of *Deltosperma*.

Deltosperma infundibuliformis Zhuang, **sp. nov.** (Fig. 16)

Ab D. caespitoso pycnidiis multo longioribus, conidiis minoribus nodulis paucioribus in superficie conspersis, consocietate cum teleomorpha Unguiculariopside infundibuliformi, et habitatione in hospite fungo alio differens.

Pycnidia arising from the stipe base of apothecium of *Unguiculariopsis infundibuliformis,* superficial, gregarious, elongated subcylindrical, cinnamon-brown to dark brown ("becoming quite black" according to Durand by misdescribing the color of a long-beaked pyrenomycete on the same substrate), 0.5-1.5 x 0.15-0.35 mm. Structure of pycnidial wall similar to that of apothecial stipe and excipulum except near the ostiole, outer layer of textura angularis, cells brown, somewhat glassy and thick-walled; inner layer hyphae light brown, slightly interwoven, more or less parallel to the outer surface. Conidiophores absent. Conidiogenous cells phialidic, some with repeating phialides, elongated lageniform to nearly cylindrical, light brown, smooth-walled, 7-12 x 2.0 μm, a few phialides with dark brown and thick walls; some hyaline, thin-walled hyphae with a blunt apex protruding from the fruiting layer. Conidia irregularly angular, deltoid to corn seed-shaped, nodulose, pale brown, unicellular, 2.9-3.4 x 2.0-2.3 μm (1-2 μm in diam according to Durand).

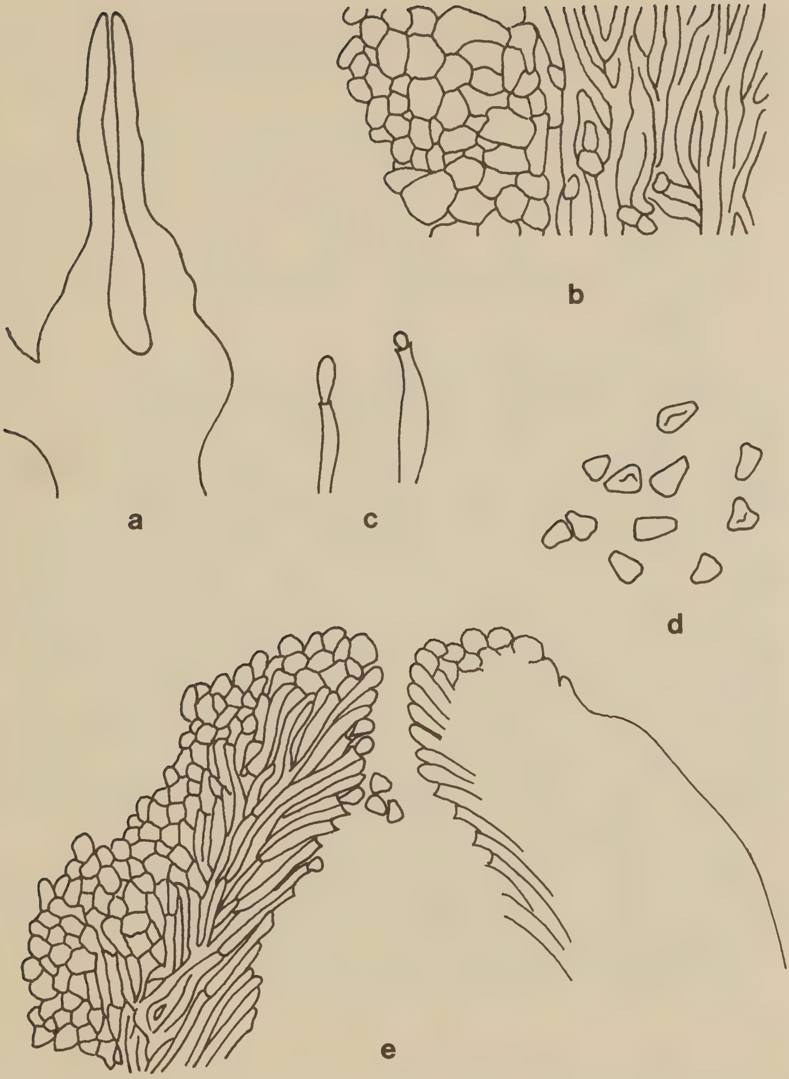


FIG. 16. *Deltosperma infundibuliformis* (holotype): **a**. pycnidium, **b**. structure of pycnidial wall, outer layer with angular cells and inner layer with interwoven hyphae, **c**. phialidic conidiogenous cells, **d**. conidia, **e**. structure of pycnidial wall at apex; **a** x 50, **b**, **e** x 1000, **c**, **d** x 1580.

HOLOTYPE: On fruit bodies of a long-beaked species of the Diatrypaceae, or associated with the fungus, Emperor Valley, Port of Spain, Trinidad, R. Thaxter 4126, XII. 1912, FH-General Herb.

10. **Unguiculariopsis livida** (Bacc.) Zhuang, **comb. nov.** (Fig. 17)

≡ *Pseudohelotium lividum* Bacc., Nuovo Giorn. Bot. Ital. 11: 419, 1904.

≡ *Mollisiella livida* (Bacc.) Sacc. & D. Sacc., Syll. Fung. 18: 64, 1906.

≡ *Pithyella livida* (Bacc.) Boud., Hist. Classif. Disc. Eur. p. 125, 1907.

Apothecium discoid to cupulate, margin enrolled, subsessile, ca. 0.3-0.6 µm in diam; hymenium and receptacle dark brown, receptacle surface roughened when dry (apothecium somewhat hairy, outside brownish, and inside purple according to Baccarini, 1904). Hairs scattered on the receptacle surface; smooth- and relatively thin-walled, not rigid, sometimes glued together by amorphous substances outside the apothecium, with a swollen base and a fine, hooked apex, pale brown at base, not becoming purple in Melzer's reagent with 10% KOH pretreatment, nonseptate, mostly with a lumen extending to the apex, 15-32 µm long. Ectal excipulum of textura angularis to textura globulosa, ca. 18-40 µm thick at margin and flanks; cells dark brown, thick-walled, ca. 5-12.5 µm in diam, axes of cells perpendicular to the outer surface. Medullary excipulum of textura intricata; hyphae light brown. Subhymenium not clear. Asci 8-spored, cylindrical, J–, pore walls not turning blue in Melzer's reagent with 10% KOH pretreatment, ca. 31-35 x 4.5-5.3 µm, with croziers at base. Ascospores uniseriate, spherical, guttulate, 3.4-4.2 µm in diam. Paraphyses filiform, septate throughout the entire length, branched, equal to or slightly exceeding asci, 1.8-2.5 µm wide.

HABITAT: On fruit bodies of ?*Karstenula* sp.

HOLOTYPE EXAMINED: [On fruit bodies of ?*Karstenula* sp.] on branches of *Robinia* sp., sul terreno ai Semplici, Italy, Settembre, 1903, FI-Herb. R. Musei Fl. #1846 (filed under *Pseudohelotium lividum*).

DISTRIBUTION: Italy.

ILLUSTRATION: This paper, Fig. 17.

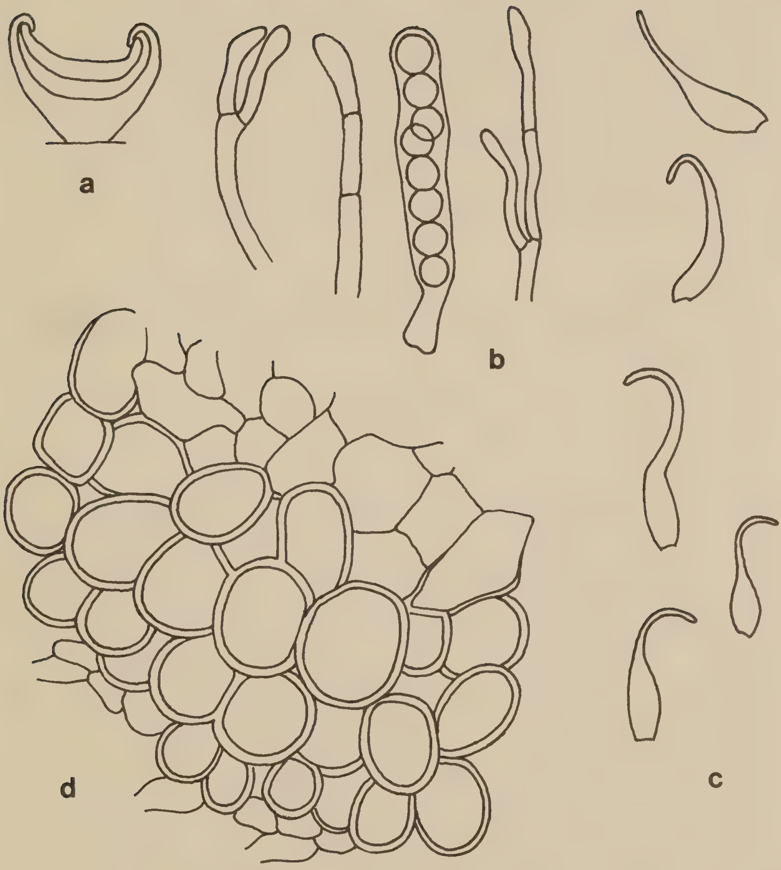


FIG. 17. *Unguiculariopsis livida* (holotype): **a**. shape of apothecium, from top to bottom showing hymenium, medullary excipulum and ectal excipulum, **b**. paraphysis apices and asci with ascospores, **c**. hairs with lumen at apex, **d**. ectal excipulum; **a** x 50, **b-d** x 1300.

EXSICCATAE EXAMINED: None.

OTHER SPECIMENS EXAMINED: None.

Notes: The excipular structure, hair morphology and habitat of this species fit the generic concept of *Unguiculariopsis* well. The fungus grows directly on fruit bodies of a ?*Karstenula* species on twigs of *Robinia* sp. There are many apothecia in the type specimen, but some were either overmature upon collecting or were being parasitized by a tiny coelomycete. The hairs appear thin-walled, not as rigid as in any other species, and sometimes glued together by amorphous substances. Therefore the individual hairs are indistinct in a section preparation (seen better in the squash mount). The paraphyses of this fungus are branched and septate throughout the entire length, while those of other species are seldom so. In addition to the above features, it differs from *U. ilicincola* in smaller apothecia and shorter asci. A new combination is therefore proposed.

11. **Unguiculariopsis parasitica** (Fckl.) Zhuang, **comb. nov.** (Fig. 18)

≡ *Cenangium parasiticum* Fckl., Jahrb. Nassauichen Vereins Naturk. 25-26: 331, 1871.

≡ *Cenangella parasitica* (Fckl.) Rehm in Rabenh., Krypt.-Fl., ed. 2, 1(3) [Lief. 31]: 232, 1889.

Original description together with my observation of young material: Apothecium discoid, orbicular or irregular, broadly stipitate to subsessile, 1-2 mm in diam, turbinate and closed at first, open and finally flattened, margin strongly elevated, involute, very dense; hymenium grey, fleshy when fresh, dark brown to nearly black when dry; receptacle surface velvety, pale dirty-grayish to yellowish brown, sometimes margin slightly paler. Hairs distributed mainly at margin and upper flanks, smooth-walled, with a swollen base and a fine curved apex, light brown at base and pale yellow at apex, not becoming purple in Melzer's reagent with 10% KOH pretreatment, nonseptate, with a lumen extending to the apex, 20-25 µm long. Ectal excipulum of textura angularis, 25-33 µm thick; cells brown, more or less thick-walled, subspherical to ellipsoid, 4-8 µm in diam if isodiametric. Medullary excipulum of textura intricata, thin at margin and very thick at base; hyphae light brown to pale brown. Subhymenium not clear in young apothecium. Asci cylindrical, 8-spored. Ascospores uniseriate, ovate, with blunt ends, biguttulate, pale yellow, 6-8 x 3-4 µm. Paraphyses filiform, septate, ca. 1.5 µm wide.

ANAMORPH: *Deltosperma caespitosum.*

HABITAT: on *Eutypa lata* (Pers. : Fr.) Tul. on *Acer* sp.

NEOTYPE: [On *Eutypa* sp., on bark,] Münhau, *Syringa* seutier Pere,

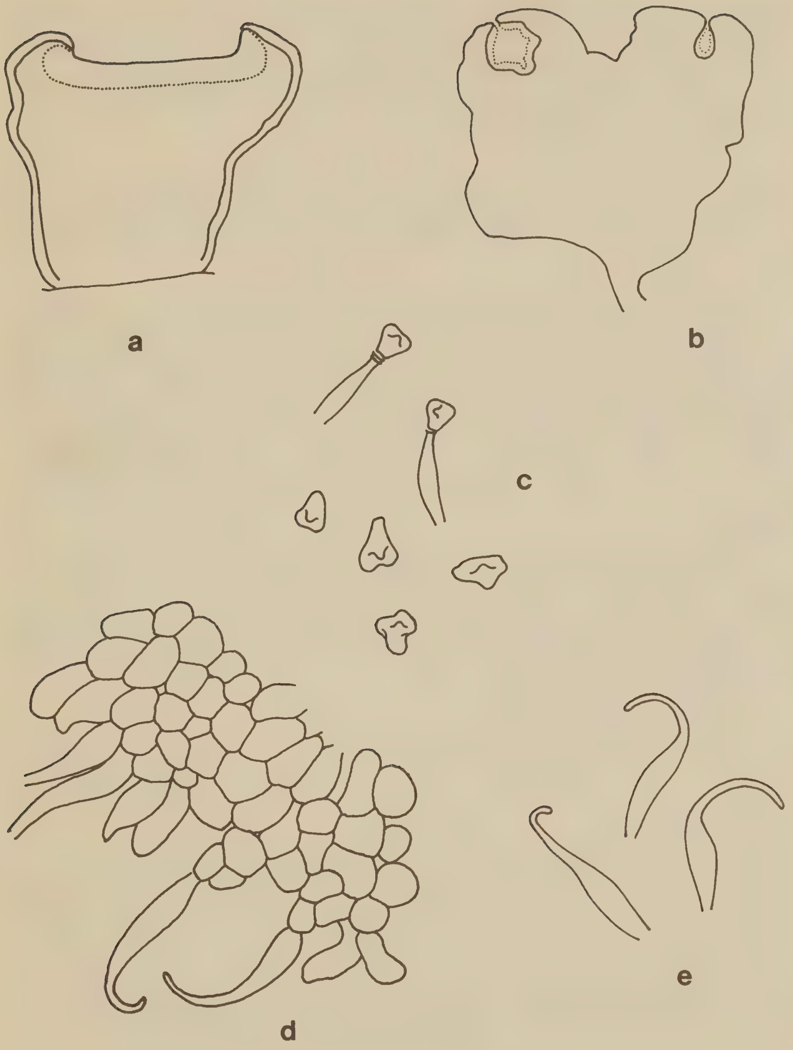


FIG. 18. *Unguiculariopsis parasitica* (isotype): **a**. shape of apothecium, from top to bottom showing hymenium, medullary excipulum and ectal excipulum, **b**. two pycnidia arising from a common basal tissue, **c**. conidia and conidiogenous cells, **d**. ectal excipulum, **e**. hairs with lumen at apex; **a, b** x 50, **c** x 1580, **d, e** x 1300.

(no collector), (no date), G 1238/4ABCD (teleomorph & anamorph) (filed under *Cenangium*, Pycnid. *Sphaeronaema caespitosum*).

EXSICCATAE EXAMINED: HERBIER BARBEY-BOISSIER: Herbier Fuckel #1131, den Pycnidium *Cenangii parasitici*, ad *Aceris* ramos putridos, raro, Autumno, Reichartshausen, Austria, L. Fuckel, (no date), BPI (anamorph), G (teleomorph & anamorph) (all filed under *Sphaeronaema caespitosum*).

OTHER SPECIMENS EXAMINED: None.

Deltosperma caespitosum (Fckl.) Zhuang, **comb. nov.** (Fig. 18 b, c)

≡ *Sphaeronaema caespitosum* Fckl., Fungi Rhenani Exs. #2147, 1868.

Pycnidia gregarious, shortly cylindrical to conical, brown 0.3-0.8 (-1.0) x 0.25 mm. Pycnidial walls with a few hooked hairs on the surface; two-layered, outer layer with brown, angular cells; inner layer with light brown, interwoven hyphae. Conidiophores absent. Conidiogenous cells annellidic, with 1-2 annellations, subcylindrical to slightly lageniform, pale brown, 7.0-9.5 x 1.5 µm. Conidia deltoid to irregularly angular, nodulose, with knobs on surface, light brown, unicellular, thin-walled, 3.0-4.4(-5.9) x 2.0-3.5 µm (3 µm in diam according to the original author).

HOLOTYPE EXAMINED: FUNGI RHENANI EXSICCATI A LEOPOLDO FUCKEL COLLECTI #2147, an faulenden Asten von *Acer platanoides*, meist auf *Eutypa* schmarotzend, selten, im Herbst. Im Park zu Reichartshausen, Austria, L. Fuckel, (no date), G (anamorph) (isotypes: BPI (anamorph), FH (anamorph), S (anamorph) (filed under *Sphaeronaema caespitosum*).

DISTRIBUTION: Austria.

ILLUSTRATION: This paper Fig. 18.

EXSICCATAE EXAMINED: FUNGI RHENANI EXSICCATI A LEOPOLDO FUCKEL COLLECTI #2147 (filed under *Sphaeronaema caespitosum*), see holotype examined.

HERBIER BARBEY-BOISSIER: Herbier Fuckel #1130, parasite sur *Eutypa* sur les rameaux de l' *Acer platanoides*, Parc de Reichartshausen, Austria, (cultivé par Fuckel), (no date), G (anamorph) (filed under *Cenangella parasitica*); Herbier Fuckel #1131, den Pycnidium *Cenangii parasitici*, ad *Aceris* ramos putridos, raro, Autumno, Reichartshausen, Austria, Fuckel, (no date), BPI (anamorph), G (teleomorph & anamorph) (filed under *Sphaeronaema caespitosum*); Herbier Fuckel #2201, ad Aceris ramos putridos, raro, Autumno, ca. Reischartshausen, Austria, (no collecter), (no date), BPI (anamorph), G (anamorph) (filed under *Sphaeronaema caespitosum*).

OTHER SPECIMENS EXAMINED: None.

Notes: The anamorph of this fungus was first found on a *Eutypa* species by Fuckel, and described in Fungi Rhenani Exsiccati a Leopoldo Fuckel Collecti #2147 under the name *Sphaeronaema caespitosum* (Fuckel, 1870). Later, he found its teleomorph and named it *Cenangium parasiticum* (Fuckel, 1871). The isotypes and several additional specimens in Fuckel's collections in BPI, FH, G, NY, and S have been borrowed and examined. Although the anamorph in every collection is in a good condition, the apothecia are absent, immature, or have fallen off from the substrate in all but two collections. Fortunately, *C. parasiticum* was described in sufficient detail that the careful observations of the original author provide many important characteristics of the fungus. The fungicolous habit, elevated and involute apothecial margin, velvety receptacle surface, dirty-grayish brown color of apothecium, and shape of ascospores are characteristic features of *Unguiculariopsis*.

The young apothecia were sectioned and observed. The anatomical structure, brown, subspherical ectal excipular cells, presence of hairs which have a swollen base and a fine, curved apex, and its association with *Eutypa lata* indicate that it is a species of *Unguiculariopsis*. The ascospores, which I have not seen, were originally described as "uniseriate, ovate, with blunt ends, two-celled, pale yellow, 6-8 x 3-4 µm." The spore shape and color are as in *Unguiculariopsis*, but "two-celled" seems wrong for this genus. From my study of the ellipsoid-spored species of this genus, I conclude that Fuckel interpreted the ovate, unicellular, biguttulate ascospores as "two-celled."

The most closely related species is *U. infundibuliformis*. The two species have common apothecial structure and congeneric anamorphs, but *U. parasitica* can easily be distinguished from *U. infundibuliformis* by the broadly and shortly stipitate (instead of long-stipitate) and smaller apothecia, size of ascospores, size of pycnidia, and size of conidia. In *U. infundibuliformis*, the pycnidia usually arise from the stipes of apothecia, while the pycnidia of *U. parasitica* often form directly on the host fungus before the apothecia appear. Even though I have not seen the mature asci and ascospores from the known collections, my observations and the original description have given enough information to transfer this species to *Unguiculariopsis*.

12a. **Unguiculariopsis ravenelii** (Berk. & Curt.) Zhuang & Korf in Zhuang, Mycotaxon 29: 395, 1987, subsp. **ravenelii** (Fig. 19)

≡ *Peziza ravenelii* Berk. & Curt., Grevillea 3: 152, 1875.

≡ *Cenangium ravenelii* (Berk. & Curt.) Sacc., Syll. Fung. 8: 568, 1889.

≡ *Encoeliella ravenelii* (Berk. & Curt.) Höhn., Sitzungsber. Kaiserl. Akad. Wiss., Math.-Naturwiss. Kl., Abt. 1. 119: 619, 1910 (nom. superfl., Art. 63.1, ICBN).

MISAPPLICATIONS:
Mollisiella ilicincola (Berk. & Br.) Mass., J. Linn. Soc. Bot. 31: 522, 1896 (pro parte).
Unguiculariopsis hysterigena (Berk. & Br.) Korf, Phytologia 21: 207, 1971 (pro parte).

Apothecium discoid to cupulate, sometimes unequal sided, margin enrolled, sometimes lobed, subsessile to substipitate, 0.6-2.0 mm in diam;

hymenium orange to orange beige when fresh in some collections, dirty orange, warm brown to brown when dry; receptacle surface furfuraceous, grayish brown to light vinaceous brown when dry (hymenium becoming reddish, receptacle white when fresh according to Berkeley and Curtis in Berkeley, 1875). Hairs scattered from margin to base of apothecium, smooth- and glassy-walled, with a swollen base and a fine, hooked apex, light brown to pale yellow at base, becoming light purple in Melzer's reagent with 10% KOH pretreatment, nonseptate, margin hairs with lumen extending to the apex, basal hairs sometimes with solid apex, (12-)15-20(-24) µm long. Ectal excipulum of textura globulosa to textura angularis, 18-55 µm thick; cells brown, somewhat thick-walled, if isodiametric 5-15 µm in diam, if ellipsoid 7-18 µm long; receptacle pustulate at base in some collections. Medullary excipulum of textura intricata; hyphae loosely interwoven, walls light brown. Subhymenium of textura intricata, often pigmented, 11-22 µm thick. Asci 8-spored, cylindrical, J–, pore walls not turning blue in Melzer's reagent with 10% KOH pretreatment, 37-51 x 4.4-5.2(-5.5) µm, arising from croziers. Ascospores uniseriate, spherical, uniguttulate, (2.5-)2.9-4.1(-4.5) µm in diam. Paraphyses filiform, sometimes deformed at apex, occasionally hair-like at apex, septum present only in lower part, sometimes branched, equal to, or slightly exceeding asci, 1.0-2.0 µm wide.

HABITAT: On hymenium of *Rhytidhysteron rufulum*, or associated with this fungus.

SYNTYPES EXAMINED: On *Rhytidhysteron rufulum* (as *Patellaria nigro-cinnabarina*), Sautee Caual, North Carolina, Ravenel 1778, (no date), FH (isosyntype: CUP-D 3603 (34-149)) (as *Peziza ravenelii*); on *R. rufulum* (as *Hysterium bicolor*), South Carolina, Ravenel 551, II. 18??, K (isosyntype: CUP-D 3604 (34-150)) (as *Peziza ravenelii*, filed under *Cenangium*).

DISTRIBUTION: Colombia, Jamaica, Peru, United States, Venezuela.

ILLUSTRATIONS: ?Massee, G., J. Linn. Soc. Bot. 31: Pl. 18, Figs. 15-18, 1896 (*Peziza ilicincola*). Seaver, F. J., Mycologia 31: 94, Fig. 1, 1939; N. Am. Cup-Fungi (Inop.). Pl. 113, 1951 (*Mollisiella ilicincola*). This paper, Fig. 19.

EXSICCATAE EXAMINED: RAVENEL, FUNGI CAROLINIANI EXSICCATI: Fasc. II, #46 (filed under *Peziza ravenelii*), on *Rhytidhysteron rufulum* (as *Hysterium rufulum*), Carolina, USA, Ravenel, (no date), CUP-D 6324 (34-151), FH, FH-General Herb., NY; Fasc. II, #47 (filed under *Hysterium rufulum*), [on *R. rufulum*] on branches of *Morus* sp., *Melia* sp. and others, Carolina, USA, Ravenel, (no date), NY.

OTHER SPECIMENS EXAMINED: COLOMBIA: [on *Rhytidhysteron rufulum*] on dead twigs, Santa Marta, C. F. Baker 103, 18. XI. 1898, CUP-D 7309(117-69) (filed under *Tryblidiella ?rufula*); [on *Rhytidhysteron rufulum*] on dead twigs, Santa Marta, C. F. Baker 103, XII. 1898, NY (filed under *Tryblidiella*); on *Rhytidhysteron rufulum*, vicinity Km Post 94, on the Choconta-Agualara Rd., Dpto. Boyaca, elev. ca 4500 ft., K. P. Dumont, S. E. Carpenter, M. A. Sherwood, & L. A. Molina, 10. VI. 1976, NY-Dumont CO 4570 (filed under

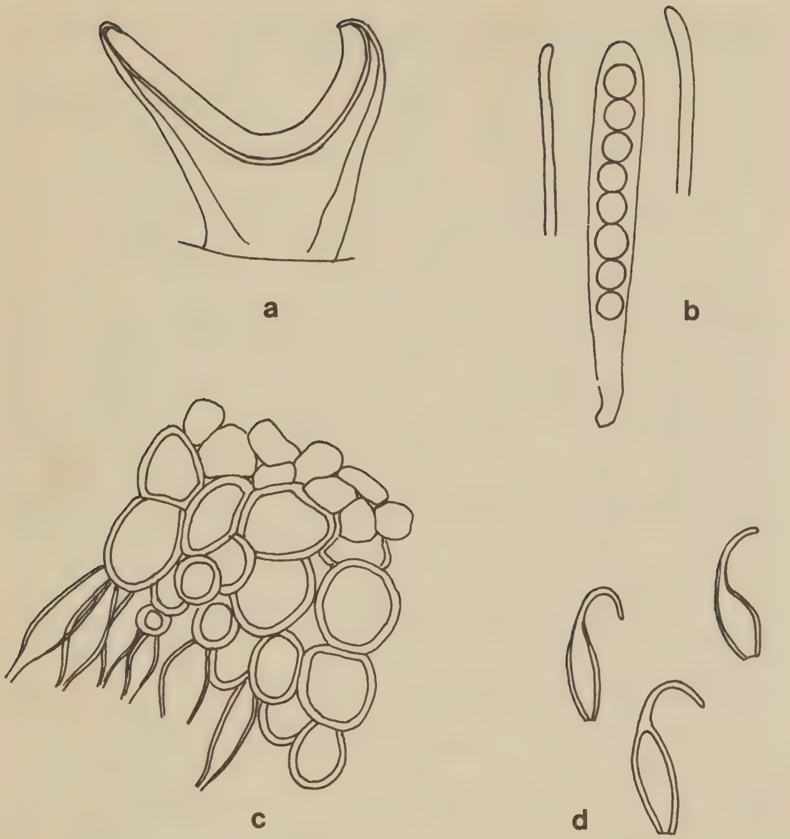


FIG. 19. *Unguiculariopsis ravenelii* subsp. *ravenelii*: **a**. shape of apothecium, from top to bottom showing hymenium, subhymenium, medullary excipulum and ectal excipulum, **b**. paraphysis apices and asci with ascospores, **c**. structure of ectal excipulum, **d**. hairs, one with a solid apex and two with lumen at apex; **a** from Ravenel 551(syntype), x 50; **b-d** from R.P.K. 2349, x 1300.

Unguiculariopsis hysterigena).

JAMAICA: On *Rhytidhysteron rufulum* on rotting twigs, creek below Pine Grove Villas, 0.9 miles north of Guava Ridge, alt. 3400 feet, St. Andrew Parish, R. P. Korf, T. Iturriaga, & W.-y. Zhuang, 8. XII. 1986, CUP-MJ 989; on *R. rufulum* on stems of *Rubus ellipticus*, creek below Pine Grove Villas, 0.9 miles north of Guava Ridge, alt. 3400 feet, St. Andrew Parish, R. P. Korf, T. Iturriaga, & W.-y. Zhuang, 8. XII. 1986, CUP-MJ 991, CUP-MJ 1017.

PERU: on *Rhytidhysteron rufulum* (as *Tryblidiella rufula*), in jungle on ridge east of Tingo María, H. A. Allard 21993d, 30. X. 1949 – 19. II. 1950, BPI (filed under *Mollisiella ilicincola*).

UNITED STATES: [On *Rhytidhysteron rufulum* (as *Tryblidiella rufula*)] on *Citrus*, Hickans, Florida, B. O. Dodge, IV. 1921, BPI (filed under *Tryblidiella rufula*); on [*R. rufulum*] on *Citrus*, Avon Park, Floida, C. L. Shear #91, 9. I. 1937, BPI (filed under *Tryblidiella rufula* var. *fusca*); on *R. rufulum* (as *Tryblidiella rufula*), Gainesville, Florida, R. K. Voorhees 12170, 15. X. 1937, BPI, FH-General Herb., FLAS 3253, 48150, NY (in three packets) (filed under *Cenangium ravenelii*); [on *R. rufulum*] on *Pistacia chinensis* Bunge, Gainesville, Florida, R. K. Voorhees 12166, 12167, 12169, 15. X. 1937, NY (filed under *Tryblidiella fusca*); [on *R. rufulum*], on *Prunus persica*, Florida, G. Weber, XII. 1937, BPI (filed under *Tryblidiella rufula* on *Lachnellula hysterigena*); on hymenium of *R. rufulum* (as *Tryblidiella* sp.) on a branch of *Persea* sp., Florida, L. Aldinger, ? I. 1938, NY (filed under *Mollisiella ilicincola*); on *R. rufulum* on *Phoradendron*, Oviedo, Florida, C. L. Shear, 14. II. 1938, FLAS 42778 (filed under *Mollisiella ilicincola*); on [*R. rufulum*] on *Rhododendron lapponicum*, Orlando, Florida, C. L. Shear #1242, 23. XII. 1939, BPI (filed under *Tryblidiella rufula* and *Mollisiella ilicincola*); [on *R. rufulum*] on *Citrus*, Maitland, Florida, C. L. Shear, 15. I. 1940, BPI (filed under *Tryblidiella rufula* var. *fusca*); on *R. rufulum* (as *Tryblidiella rufula*), Clermont, Florida, C. L. Shear, 7. III. 1942, BPI (filed under *Tryblidiella rufula* parasitized by *Mollisiella ilicincola*); on *R. rufulum* (as *Tryblidiella rufula*), on *Phoradendron flavescens*, Oviedo, Florida, C. L. Shear, 2. III. 1943, BPI (filed under *Mollisiella ilicincola*); [on *R. rufulum*] on *Citrus paradisi*, W. of Vero Beach, Florida, A. S. Rhoads, 21. II. 1944, BPI (filed under *Tryblidiella rufula*); on *R. rufulum* on *Citrus sinensis*, W. of Vero Beach, Florida, A. S. Rhoads, 21. II. 1944, BPI (filed under *Tryblidiella rufula*); [on *R. rufulum*] on dead sprout of chinaberry (*Melia azedarach* L.), Experiment Station grounds, Gainesville, Alachua Co., Florida, A. S. Rhoads, 13. IV. 1944, BPI (filed under·*Tryblidiella rufula*); on *R. rufulum*, Winter Park, Florida, F. J. Seaver, summer, 1949, R.P.Korf pers. herbarium 2349 (filed under *Unguiculariopsis hysterigena*); on *R. rufulum* (as *Hysterium bicolor*), North America, (no collector), (no date), FH-Höhnel Herb. (filed under *Peziza ravenelii*).

VENEZUELA: On *Rhytidhysteron rufulum* on dead twig, beach opposite Churuata de Armando Subero, Rio Cunucunuma, on a wooded, humid hill, Amazonas, T. Iturriaga, 17. I. 1987, VEN 790; on *R. rufulum* on cortex of a fallen tree, Warima besides Rio Acanan, close to Amaruai-tepui, Estado Bolivar, T. Iturriaga, 22. III. 1987, VEN 911.

Notes: For distinctions between this fungus and the two most closely related species, see notes for *Unguiculariopsis hysterigena* and *U. ilicincola*. *U. ravenelii* is relatively common in the United States and South America.

Fresh material was collected in Jamaica. The ascospores shot on PDA medium germinated within 24 hours. The germ tubes grew slowly and became branched, but the fungus hardly produced a colony after a long time (more than 7 months). Hyphal swellings formed in the culture. Some of the germ tubes stopped extending, and the fungus died (Zhuang, 1987). In nature, this species usually occurs on the decaying fruit bodies of *Rhytidhysteron rufulum.*

12b. **Unguiculariopsis ravenelii** subsp. **hamata** (Chen.) Zhuang, **comb. nov.** (Fig. 20)

≡ *Pithyella hamata* Chen., Bull. Soc. Mycol. France 34: 39, Pl. 3, Fig. 3, 1918.

Apothecium discoid to cupulate, sometimes unequal sided, margin enrolled, subsessile to substipitate, 0.4-0.9(-1.3) mm in diam; hymenium grayish brown to olive brown when dry; receptacle surface furfuraceous, grayish brown to yellowish brown when dry. Hairs scattered from margin to base of apothecium smooth-walled, with a swollen base and a fine, hooked apex, light brown to pale yellow at base, not or slightly becoming purple in Melzer's reagent with 10% KOH pretreatment, nonseptate, marginal hairs with lumen extending to the apex, basal hairs sometimes solid at apex, 15-29 µm long. Ectal excipulum of textura globulosa to textura angularis, 13-45 µm thick; cells brown, somewhat thick-walled, if isodiametric 5-14 µm in diam, if ellipsoid 9.5-17 x 5-12.5 µm. Medullary excipulum of textura intricata; hyphal walls light brown. Subhymenium of textura intricata; hyphae pale yellow, 11-15 µm thick. Asci 8-spored, cylindrical, J–, pore walls not turning blue in Melzer's reagent with 10% KOH pretreatment, 43-51 x 4.5-6.0 µm, arising from croziers. Ascospores uniseriate, spherical, uniguttulate, 3.5-4.9 µm in diam. Paraphyses filiform, exceeding asci by 2-7 µm, 1.5-2.0 µm wide.

HABITAT: On hymenium of *Rhytidhysteron hysterinum* or associated with this fungus.

NEOTYPE: On *Rhytidhysteron hysterinum* on *Buxus sempervirens*, boxwood thicket, just W. of Lizonne River, Aizie, near Ruffec, Dept. Chanente, F. Candoussau, T. Iturriaga, R. P. Korf, & W.-y. Zhuang, 20. IX. 1987, CUP 61819 (isoneotypes: Pers. Herb. F. Candoussau 4371, VEN).

DISTRIBUTION: China, France, Surinam.

ILLUSTRATIONS: Chenantais, J.-E., Bull. Soc. Mycol. France 34: Pl. III, Fig. 3, 1918. This paper, Fig. 20.

EXSICCATAE EXAMINED: RELIQUIAE FARLOWIANAE: #915 (filed under *Tryblidiella hysterina*), [on *R. hysterinum* on dead stem], Huei Hsiang Ping, Chiang Kou Hsien, Pan Ching Shan, Guizhou (as Kweichow) Province, China, S. Y. Cheo 727, 17. X. 1931, FH, FH-General Herb.

OTHER SPECIMENS EXAMINED: CHINA: [On *Rhytidhysteron hysterinum*] on dead stem of *Berchemia*, Ta Ho Yen, Chiang Kou Hsien, Pan Ching Shan, Guizhou (as Kweichow) Province, S. Y. Cheo 552, 21. IX. 1931, FH-General Herb., NY (filed under *Tryblidiella* sp.); On *Tryblidiella* sp. [*R. hysterinum*], Hui Hsing Ping, Kiang Kan Hsien, Guizhou (as Kweichow) Province, S. Y. Cheo 640, 3. X. 1931,

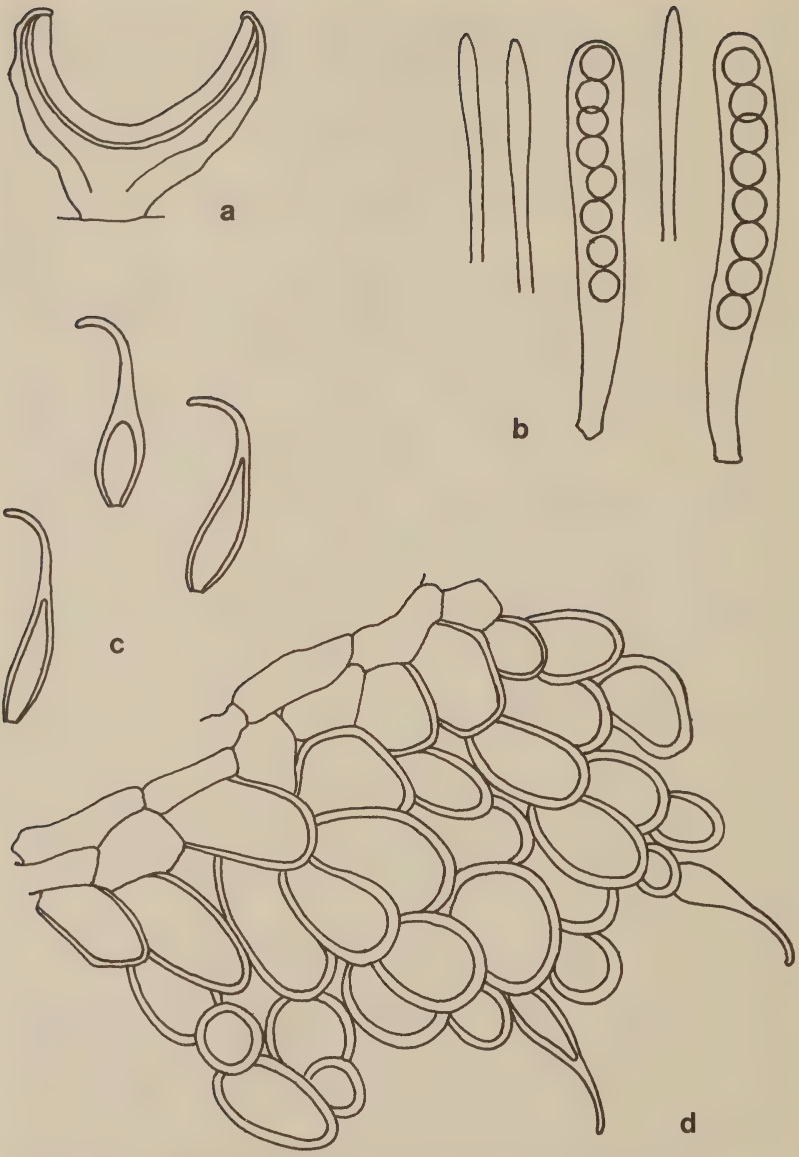


FIG. 20. *Unguiculariopsis ravenelii* subsp. *hamata* (FH-Cheo 640): **a**. shape of apothecium, from top to bottom showing hymenium, subhymenium, medullary excipulum and ectal excipulum, **b**. paraphysis apices and asci with ascospores, **c**. hairs solid at apex, **d**. structure of ectal excipulum at flank; **a** x 50, **b-d** x 1300.

FH-General Herb. (filed under *Lachnellula hysterigena*); [on *R. hysterinum*] on dead stem, Huei Hsiang Ping, Chiang Kou Hsien, Pan Ching Shan, Guizhou (as Kweichow) Province, S. Y. Cheo 727, 17. X. 1931, FH-General Herb. (filed under *Tryblidiella hysterina*).

FRANCE: on stipe and beside *Rhytidhysteron hysterinum* on *Buxus sempervirens*, Luz St. Sauveur (Tennis) Hautes Pyrénées, F. Candoussau, 5. IX. 1987, F. Candoussau 4372-A, CUP 61820, HMAS; on *Rhytidhysteron hysterinum* and *Buxus sempervirens*, Luz St. Sauveur Tennis (env. Lourdes), F. Candoussau, 27. IX. 1987, F. Candoussau Pers. Herb. 4371.A, CUP 61855, HMAS.

SURINAM: [On hymenium of *Rhytidhysteron hysterinum*], Kamp 8: 500 meter path east of camp, A. L. Welden 2444, 11. VII. 1961, NY (filed under *Tryblidiella insculptum*); [on hymenium of *R. hysterinum*] swamp forest and adjacent mesophytic forest, along road W. to S. of Kamp 8, A. L. Welden 2562, 14. VII. 1961, NY (filed under *Tryblidiella elevata*).

Notes: Three collections of *Unguiculariopsis* from Guizhou Province, China, one labelled *Lachnellula hysterigena* and two as *Tryblidiella hysterina*, were found in the Farlow Herbarium of Harvard University, and two collections from Surinam labelled *Tryblidiella* species were found in the New York Botanical Garden. My examination of these materials indicate that they are very similar to *U. ravenelii* but differ from that fungus in longer hairs which do not turn purple in Melzer's reagent, wider asci, larger ascospores, and occurrence on *R. hysterinum* instead of *R. rufulum*.

Pithyella hamata Chenantais (1918) which occurs on *R. hysterinum* (as *Triblydium hysterinum*) on *Buxus* in France is very similar to the Chinese and Surinam fungus. But the type of *P. hamata* no longer exists (Baudouin, pers. comm.). A special searching trip was arranged to the Muséum d'Histoire Naturella de Nantes (NTM), Nantes, France where Chenantais herbarium is located. Unfortunately, Chenantais's discomycete specimens were discarded by a French mycologist who felt they had little or no value. In order to recognize the lost species, with the kind assistance of Mme F. Candoussau and Mr. E. Chollet, a successful collecting trip to Ruffec where the type specimen of *P. hamata* had been originally found was carried out to recollect the fungus. CUP 61819 is here designated as the neotype of *Pithyella hamata* Chen.

13. **Unguiculariopsis rehmii** Zhuang & Korf, **sp. nov.** (Fig. 21)
MISAPPLICATIONS:

Unguiculariopsis ilicincola (Berk. & Br.) Rehm, sensu Rehm, Ann. Mycol. 7: 400, 1909.

Mollisiella ilicincola (Berk. & Br.) Mass. sensu Höhnel, Sitzungsber. Kaiserl. Akad. Wiss., Math.-Naturwiss. Kl, Abt.1. 119: 620, 1910.

Ab U. ilicincola ascis fusoideis, ascosporis minoribus, et paraphysibus breoissimis 4 µm brevioribus quam ascis differens.

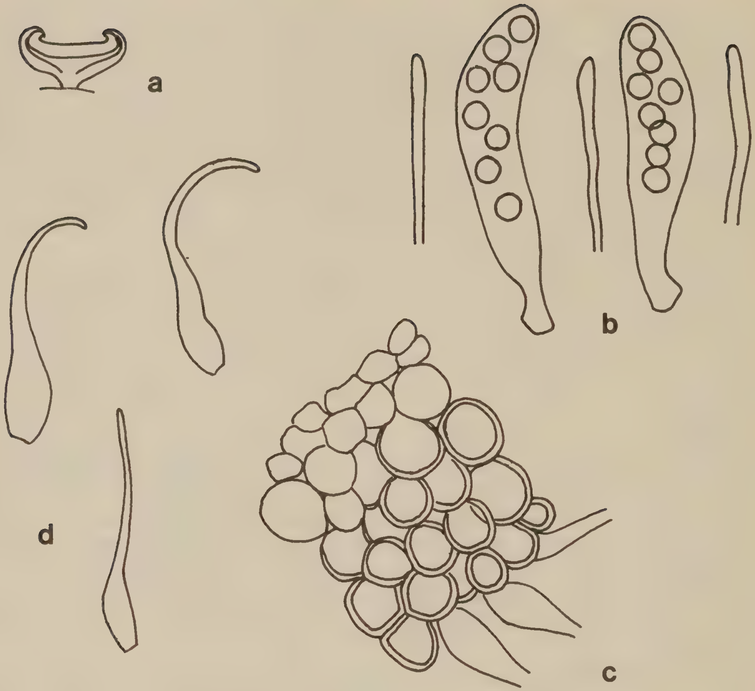


FIG. 21. *Unguiculariopsis rehmii* (holotype): **a**. shape of apothecium, from top to bottom showing hymenium, medullary excipulum and ectal excipulum, **b**. paraphysis apices and asci with ascospores, **c**. structure of ectal excipulum, **d**. hairs with lumen at apex; **a** x 50, **b-d** x 1300.

Apothecium cupulate, margin enrolled, substipitate, 0.2-0.4 mm in diam; hymenium vinaceous brown when dry; receptacle furfuraceous, grayish brown when dry (hymenium pale yellow, receptacle pale brown, white pruinose when fresh, according to Rehm). Hairs scattered from margin to base of apothecium, smooth-walled, with a swollen base and a fine, hooked apex, pale brown to subhyaline, not becoming purple in Melzer's reagent with 10% KOH pretreatment, nonseptate, with lumen extending to the apex, 22-26(-30) µm long. Ectal excipulum of textura globulosa to textura angularis, 15-37 µm thick; cells brown, somewhat thick-walled, isodiametric, ca. 5-10 µm in diam. Medullary excipulum of textura intricata, ca. 9-16 µm thick; hyphal walls subhyaline. Subhymenium indistinguishable. Asci 8-spored, subfusoid to broadly clavate, J–, pore walls not turning blue in Melzer's reagent with or without KOH pretreatment (J+ according to Rehm, 1914), 29-33 x 6.0-7.6 µm. Ascospores biseriate, spherical, guttulate, 2.8-3.3 µm in diam. Paraphyses cylindrical, nonseptate, not branched, about 4 μm shorter than apices of asci, 1.5 μm wide.

HABITAT: On *Cucurbitaria berberidis*.

HOLOTYPE: On *Cucurbitaria berberidis*, Ybbsitz, N-Oesterreich, Austria, Lambert, comm. & O. S. B. Strasser, CUP-D 11987 (104-91) (ex Rehm Ascom. #1831, the duplicates of this exsiccata are all isotypes) (filed under *Unguiculariopsis ilicincola*).

DISTRIBUTION: Austria.

ILLUSTRATION: This paper, Fig. 21.

EXSICCATAE EXAMINED: REHM ASCOMYCETES #1831 (filed under *Unguiculariopsis ilicincola*): On *Cucurbitaria berberidis*, Ybbsitz, N-Oesterreich, Austria, Lambert, comm. & O. S. B. Strasser, FH, FH-Höhnel Herb., NY (isotypes).

OTHER SPECIMENS EXAMINED: None.

Notes: When Rehm (1909) erected his monotypic genus *Unguiculariopsis*, *Peziza ilicincola* on *Myriangium* was the only species involved. But what he actually described was another fungus that had been issued in his Ascomycete Exsiccati #1831, and occurs on *Cucurbitaria berberidis*. This fungus is distinguished by its small excipular cells, fusoid asci, very small ascospores, and short paraphyses which are 4 μm shorter than the hymenium surface. In the Farlow Herbarium of Harvard University, I found among Höhnel's collections a specimen label of this fungus, on which the specific epithet of *Unguiculariopsis ilicincola* was crossed out, and re-written as "*pistroma*" by Höhnel (unpublished). I agree with Höhnel that Rehm #1831 is not *U. ilicincola* but an independent species of this genus. Since Rehm described this species, and erected the genus *Unguiculariopsis*, we named this species *U. rehmii*.

14a. **Unguiculariopsis robergei** (Desm.) Korf & Zhuang, **comb. nov.**, subsp. **robergei** (Fig. 22)

≡ *Peziza robergei* Desm., Ann. Sci. Nat. Bot. Ser. 3, 3: 365, 1845.

≡ *Lachnella robergei* (Desm.) Sacc., Syll. Fung. 8: 395, 1889.

≡ *Unguiculella robergei* (Desm.) Dennis, Kew Bull. 10: 136, Fig., 1955.

Apothecium discoid to cupulate, margin slightly enrolled, sessile, 0.5-0.8 mm in diam; hymenium light vinaceous brown when dry; receptacle surface furfuraceous, lighter than the color of the hymenium (apothecium brick-red when fresh, becoming paler during drying according to Desmazières). Hairs distributed more at margin and upper flanks than at base, smooth-walled, with a wider base, tapered towards the tip, ending with a fine and hooked apex, light brown at base, subhyaline at apex (hairs brick-red except at margin where the hairs are hyaline according to Desmazières), not becoming purple in Melzer's reagent with 10% KOH pretreatment, nonseptate, apex of some hairs solid, some with lumen, 44-65 μm long. Ectal excipulum of textura angularis to textura globulosa, 11

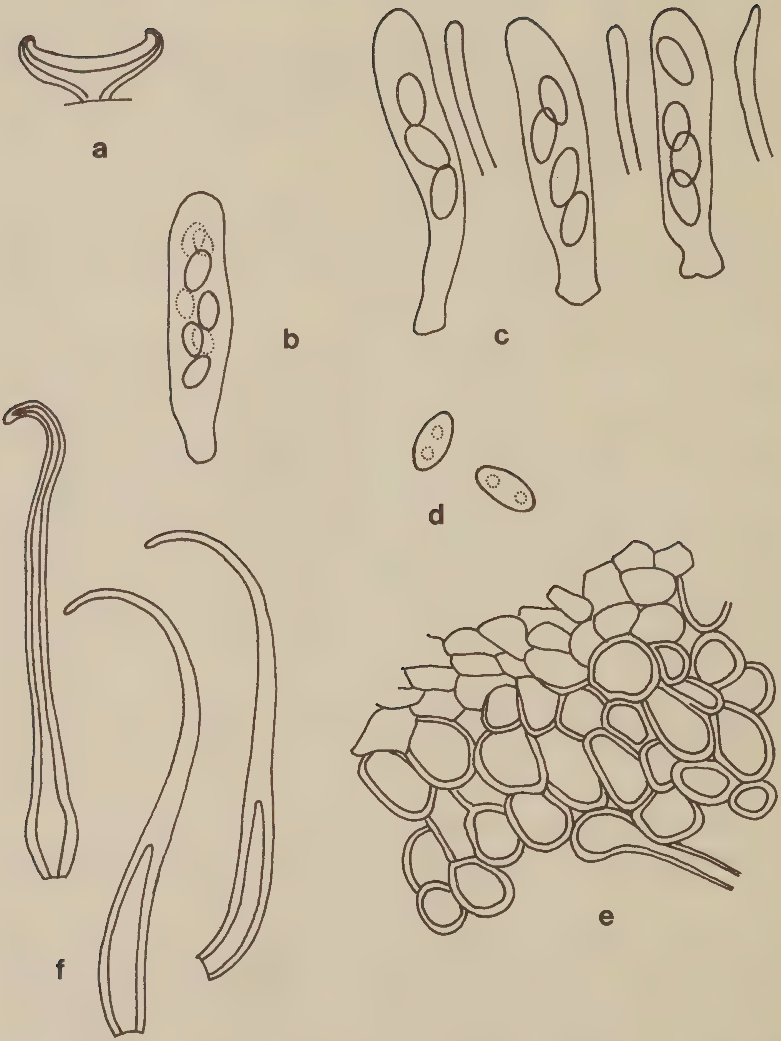


FIG. 22. *Unguiculariopsis robergei* subsp. *robergei* (isotype): **a**. shape of apothecium, from top to bottom showing hymenium, medullary excipulum and ectal excipulum, **b**. a young ascus with four developing spores and four abortive spores, **c**. paraphysis apices and mature asci with ascospores, **d**. ascospores, **e**. structure of ectal excipulum, **f**. hairs, two with a solid apex and one with lumen at apex; **a** x 50, **b-f** x 1300.

-24 µm thick; cells brown, walls thicker in the outer layers, becoming thinner inside, isodiametric to ellipsoid, ca. 5-10 µm in diam, axes of cells perpendicular to the outer surface. Medullary excipulum of textura intricata, thin; hyphae slightly brown. Subhymenium indistinguishable. Asci 8-spored when young, 4-spored at maturity, with cytoplasm inside the ascus, clavate, J–, pore walls not turning blue in Melzer's reagent with 10% KOH pretreatment, 29-33 x 5.0-6.6 µm at maturity, longer when young. Ascospores biseriate when young, uniseriate or irregularly uniseriate, occasionally biseriate at maturity, ellipsoid, subhyaline to pale yellow, biguttulate, 4.4-7.3 x 2.7- 3.5 µm. Paraphyses filiform, 2-3 septate, sometimes branched at base, not exceeding asci, ca. 1.5 µm wide.

HABITAT: On or among the fruit bodies of *Amphisphaerella xylostei* on *Lonicera* sp.

HOLOTYPE EXAMINED: [On or among *Amphisphaerella xylostei*] on *Lonicera* sp., (no locality), PLANTES CRYPTOGAMS DE FRANCE: Desmazières 1416, (no date), PC.

DISTRIBUTION: France.

ILLUSTRATIONS: Dennis, R.W.G., Kew Bull. 10: 136, Fig., 1955 (*Unguiculella robergei*). ?Dennis, R.W.G., Brit. Ascom. Fig. 29 D, 1968,(1st. ed.), 1978 (2nd. ed.) (*Unguiculella robergei*). This paper, Fig. 22.

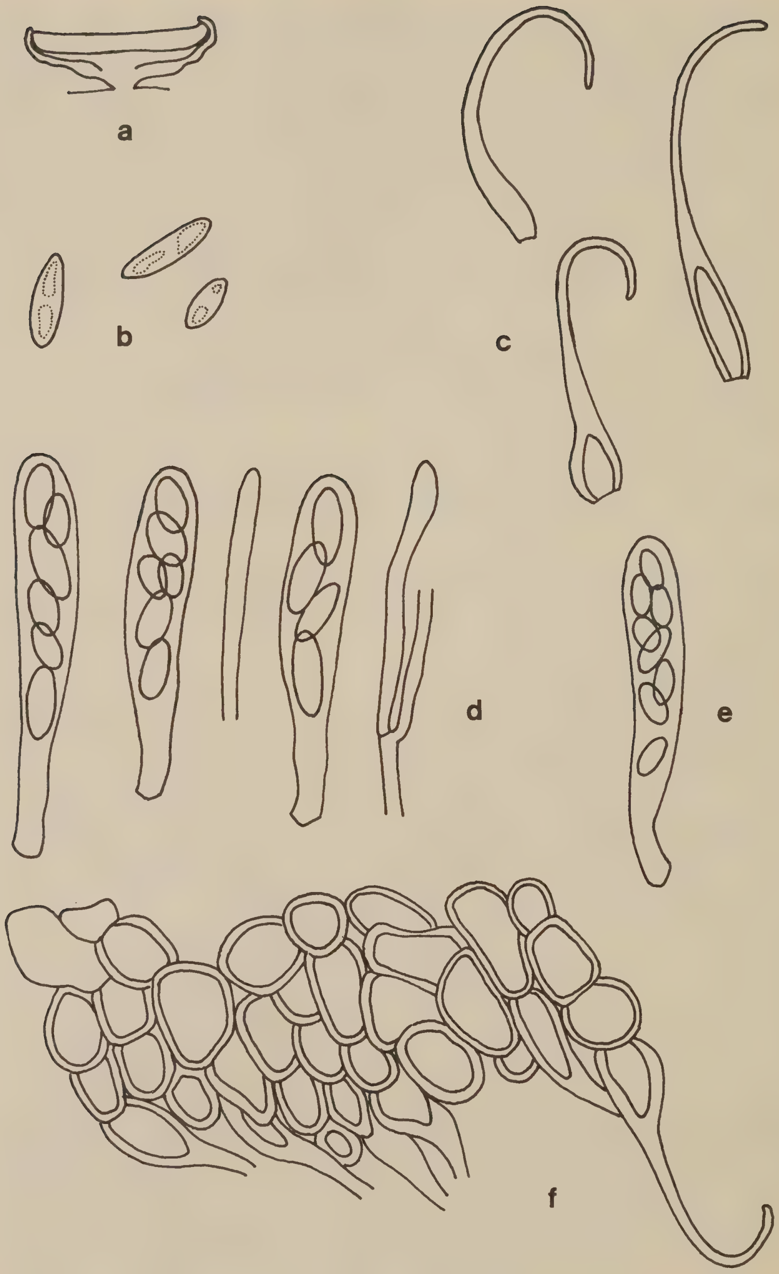
EXSICCATAE EXAMINED: PLANTES CRYPTOGAMS DE FRANCE (filed under *Peziza robergei*): [On or among *Amphisphaerella xylostei*] on *Lonicera* sp., (no locality), Desmazières 1416, (no date), FH, NY (isotypes).

OTHER SPECIMENS EXAMINED: None.

Notes: This species differs from *U. thallophila* by its longer hairs with solid apices, its wider and 4-spored asci, and its occurrence on a fungus instead of on lichens. The distinctions between *U. robergei* and *U. acerina* have been stated in the notes of the latter species. Dennis (1955) placed this species in *Unguiculella*, a genus possessing light-colored tissues, hooked hair apices and hooked paraphysis apices (Höhnel, 1906; Raitviir, 1970). But light-colored tissues and hooked paraphysis apices have never been found in the type of *U. robergei*.

My examinations of isotypes indicated that the mature asci are 4-spored, the hairs are wider at the base and tapered toward the apex, and the hair length is 44-65 µm. My observations agree with Dennis's description and illustration of the type (Dennis, 1955), but differ from his later illustrations in which the asci are 8-spored, the hairs are swollen at base, and the host range is extended to include *Rosa* sp., et al. Neither did Dennis describe the number of ascospores per ascus, nor explain the changes of the illustrations in his papers. I suspect that his later illustrations were based on collections other than the type specimen (Dennis, 1968, 1978). The new information that I find is that the host fungus is *Amphisphaerella xylostei*.

When a collection of *U. robergei* on the canker of a *Rosa* species on deposit at the Royal Botanic Gardens, Kew, England was borrowed, I found that it differs from the type of *U. robergei* in a few aspects. I name


a
b
c
d
e
f

it as *U. robergei* subsp. *coelomyceticola*, and describe and discuss it below.

14b. **Unguiculariopsis robergei** subsp. **coelomyceticola** Zhuang, **subsp. nov.** (Fig. 23)

Ab U. robergei subsp. robergei ascosporis multo longioribus, pilis brevioribus, et hospite fungo coelomycetaceo differens.

Apothecium cupulate to discoid when dry, discoid to flat when rehydrated, margin enrolled, sessile, 0.2-0.4 mm in diam when dry, up to 0.7 mm when rehydrated; hymenium light vinaceous brown to warm brown when dry; receptacle surface furfuraceous, brown when dry. Hairs distributed mainly at margin and upper flanks, smooth-walled, with a swollen base and and a fine, hooked apex, light brown at base, pale yellow at apex, not purple in Melzer's reagent with 10% KOH pretreatment, nonseptate, relatively thick-walled, solid at apex, 22-45 µm long. Ectal excipulum of textura angularis, 14-34 µm thick; cells brown, somewhat thick-walled, isodiametric to ellipsoid, 6-12 µm in diam if isodiametric, up to 18 µm long if ellipsoid, axes of cells perpendicular to the outer surface. Medullary excipulum of textura intricata, 13-26 µm thick; hyphae pale brown. Subhymenium indistinguishable. Asci 8-spored when young, 4- or mostly 6-spored, occasionally 8-spored at maturity, clavate, J– in Melzer's reagent with 10% KOH pretreatment, 31-42 x 6.0-7.0 µm, arising from croziers. Ascospores uniseriate to irregularly biseriate, ellipsoid to elongate-ellipsoid, biguttulate, subhyaline, 6.3-10.2 x 2.4-3.1 µm. Paraphyses filiform, septate, branched at both apex and base, deformed and slightly enlarged at apex, exceeding asci by ca. 5-7 µm, 1.5-2.0 µm wide.

HABITAT: On fruit bodies of a *Septoriella*-like coelomycete causing canker of *Rosa* sp.

HOLOTYPE: On fruit bodies of a *Septoriella*-like coelomycete on *Rosa* sp., Kilmory Cliffs, Isle of Rhum, Great Britain, R. W. G. Dennis, 13. IV. 1961, K (filed under *Unguiculella robergei*).

DISTRIBUTION: Great Britain.

ILLUSTRATION: This paper, Fig. 23.

EXSICCATAE EXAMINED: None.

OTHER SPECIMENS EXAMINED: None.

Notes: This fungus was identified as *Unguiculella robergei* by Dennis. It is, indeed, similar to that fungus in the presence of some

FIG. 23. *Unguiculariopsis robergei* subsp. *coelomyceticola* (holotype): **a**. shape of apothecium, from top to bottom showing hymenium, medullary excipulum and ectal excipulum, **b**. ascospores, **c**. hairs, two with a solid apex and one with lumen at apex, **d**. 4- or 6-spored mature asci and paraphysis apices, **e**. 8-spored young ascus, **f**. structure of ectal excipulum; **a** x 50, **b-f** x 1300.

4-spored asci, width of ascospores, solid hair apex, and pale brown, interwoven hyphae in the medullary excipulum. But *Unguiculariopsis robergei* subsp. *coelomyceticola* can be separated from *U. robergei* subsp. *robergei* by the longer and mostly 6-spored asci, much longer ascospores, and shorter hairs. I treat these distinctions at the level of subspecies.

The host of *U. robergei* subsp. *coelomyceticola* is a special fungus. It causes the canker of a *Rosa* species, has stromatized pycnidia, and hyaline, subcylindrical, 4- to 5-septate conidia. It may be similar to *Septoriella* except that lacks a gelatinous cap at the apex of the conidia. I am not able to name it, and I indicate it as a *Septoriella*-like fungus for the time being.

15. **Unguiculariopsis thallophila** (Karst.) Zhuang, **comb. nov.** (Fig. 24)

≡ *Trochila thallophila* Karst., Fung. Fenn. Exs. #823, 1869.

≡ *Mollisia thallophila* (Karst.) Karst., Bidr. Känned. Finl. Natur Folk 19: 205, 1871.

≡ *Pyrenopeziza thallophila* (Karst.) Sacc., Syll. Fung. 8: 370, 1889.

≡ *Skyttea thallophila* (Karst.) Sherw. & Hawksw., Trans. Brit. Mycol. Soc. 75: 489, 1980.

Apothecium cupulate, margin enrolled, sessile, 0.2-0.5 mm in diam; hymenium and receptacle dark brown when dry (apothecium dark brown or very dark brown when fresh according to Karsten, 1870, 1871); receptacle surface downy. Hairs occurring at margin and the upper flanks of apothecium, smooth-walled, with a wide base and a fine, hooked apex, pale brown to subhyaline at base, not becoming purple in Melzer's reagent with 10% KOH pretreatment, nonseptate, with lumen extending to the apex, 10-34 µm long. Ectal excipulum of textura angularis to textura globulosa, 17-30(-50) µm thick; cells brown, thick-walled, ca. 5-12 µm in diam, axes of cells perpendicular to the outer surface; receptacle surface undulate. Medullary excipulum of textura intricata; hyphal walls pale brown to subhyaline. Subhymenium indistinguishable. Asci 8-spored, clavate, J–, pore walls not turning blue in Melzer's reagent with 10% KOH pretreatment, 33-42 x 5.7-7.7 µm, with crozier at base, with empty asci in hymenium. Ascospores mostly biseriate, some irregularly uniseriate, ellipsoid, walls hyaline to subhyaline, biguttulate, (6.0-)7.3-8.8 x (2.3-)2.8-3.4(-3.7) µm. Paraphyses filiform, septate, branched or deformed at apex, not exceeding asci, ca. 1.5 µm wide.

HABITAT: On mycelia and apothecia of *Lecanora carpinea* on different plants.

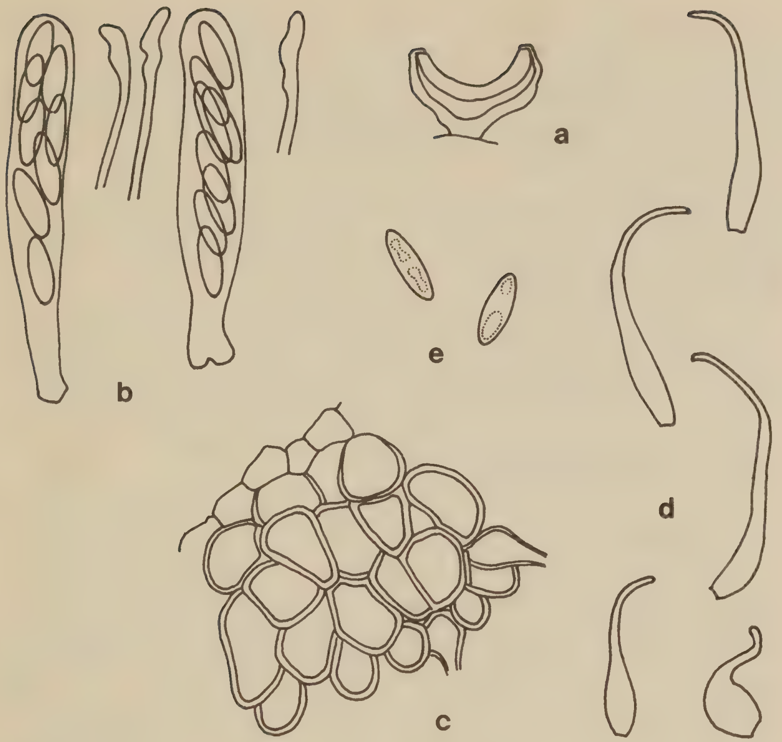


FIG. 24. *Unguiculariopsis thallophila* (H-Herb. Karsten 2579): **a**. shape of apothecium, from top to bottom showing hymenium, medullary excipulum and ectal excipulum, **b**. paraphysis apices and asci with ascospores, **c**. structure of ectal excipulum, **d**. hairs with lumen at apex (two short hairs at bottom from holotype), **e**. ascospores; **a** x 50, **b-e** x 1300.

HOLOTYPE EXAMINED: Fungi Fenniae Exs. #823, on *Lecanora carpinea,* Tavastia australis, Tammela, Mustiala, P. A. Karsten, XII. 1868, H (filed under *Trochila thallophila*) (the duplicates of this exsiccata are all isotypes).

DISTRIBUTION: Finland, Scotland, Spain, Sweden.

ILLUSTRATIONS: Dennis, R.W.G., Kew Bull. 1950: 186, Fig. 8, 1950 (*Mollisia thallophila*). Hawksworth, D.L., Notes Roy. Bot. Gard. Edinburgh 38: 171, Fig. 3, 1980 (*Pyrenopeziza thallophila*). This paper, Fig. 24.

EXSICCATAE EXAMINED: FUNGI FENNIAE EXSICCATI # 823 (filed under *Trochila thallophila*), see holotype examined.

OTHER SPECIMENS EXAMINED: FINLAND: On *Lecanora carpinea,* Tavastia australis, Tammela, Mustiala, P. A. Karsten, 24. IV. 1869, H-Karsten 2579 (as *Mollisia thallophila*); on *Lecanora carpinea* (as *Ad Lecanoram subfuscam var., ad Salic. viminalem.*), (no locality), P. A. Karsten, 24. IV. 1869, H-Karsten 2900 (as *Peziza (Trochila) erratica*); [on *Lecanora carpinea*], Tavastia australis, Tammela, Mustiala, P. A. Karsten, 12. XII. 1869, H-Karsten 2578 (as *Pyrenopeziza* and *Trochila thallophila*).

SCOTLAND: On *Lecanora chlarotera* Nyl. s. lat., on *Populus tremula* twigs, Mid-Perthshire, Balliemore, by B847 road to Struan, B. J. Coppins 156, 23. III. 1986, E (filed under *Pyrenopeziza thallophila*), IMI 237272 (filed under *Skyttea thallophila*).

SWEDEN: [On *Lecanora*], Närke: Götlunda parish, Balgbergen, skär 9 fran björk, R. Johansson & E. Julin, 29. VII. 1927, UPS; on *Lecanora carpinea* on *Sorbus aucuparia*, Uppland: Alsike parish, Lunsen, at the field S.W. of Hjortronmossen, R. Santesson, 23. IX. 1947, UPS; on *Lecanora* on *Populus tremula* in a small *Populus* grove, Uppland: Vendel parish, 1.5-2 km N.E. of Kjettslirge, R. Santesson, 28. V. 1955, UPS (filed under *Skyttea thallophila*).

Notes: When Nannfeldt (1932) examined the authentic material, he noted that it is not a species of *Pyrenopeziza* but related to *Hyaloscypha*. Dennis ((1950) indicated that the apothecial color of this fungus is different from most species of *Hyaloscypha* and that the systematic position of this species is uncertain. Santesson (1960) reported that he had collected this species in northern Spain and that the fungus is rather common in Sweden. He noted it under "*Pyrenopeziza*" *thallophila*, and thought that the fungus represents a new genus separated from *Hyaloscypha*. Later, this fungus was transferred to the lichenicolous genus *Skyttea* when the genus was first erected (Sherwood, et al., 1980). In discussing the taxonomic situation, the authors pointed out that "this species is not made the holotype of *Skyttea*, however, as it differs in some important respects from *S. mitschkei* and most other species accepted in the genus." The holotype and three additional specimens of *U. thallophila* from Finland have been examined, and they are uniform in morphology. It is very clear that *U. thallophila* possesses the following important features which are lacking in *Skyttea*: apothecia superficial, the presence of distinct hairs that have a swollen base and a fine, hooked apex, asci without a thickened apex, and the angular to globose excipular cells.

Most apothecia of the holotype from Finland, a collection from Scotland, and three from Sweden possess short hairs (10-20 µm long), but those of three other collections from Finland have relatively long hairs (15-34 µm long). Since the excipular structure and other features of these specimens are indistinguishable, I do not treat the variation in hair length as significant.

Mollisia lesdainii (Vouaux) Vouaux (1914) was also reported on a *Lecanora* species, *L. effusa*. Through the kindness of Dr. J. Astier and Prof. Y. Rondon I was able to look at the type specimen of this fungus. *M. lersdainii* differs from *U. Thallophila* in several aspects. Fuirther studies will be reported later.

ERRATUM, VOLUME THIRTY-TWO

Page 64 line 31 for *mitschkei* read *nitschkei*

EXCLUDED SPECIES

Mollisia subgenus *Mollisiella*, *Mollisiella*, and *Pithyella* have been employed by some mycologists to accommodate a few species of *Unguiculariopsis*. *Mollisiella* Boudier (1885) was established based on *Peziza perparvula* Karst., but Boudier later (1907) removed this species from *Mollisiella* to *Micropodia* Boud. Instead of discarding *Mollisiella*, he retained this generic name and added many unrelated taxa, so that the genus lost its original sense. The genus *Mollisiella* Rehm (1892) was raised from *Mollisia* subgenus *Mollisiella* Phill. (1887), which included nine unrelated species, and is entirely different from Boudier's *Mollisiella*. *Pithyella* Boud. has been reviewed recently and is an older name for *Helotiopsis* Höhn. (Korf & Zhuang, 1987). The following list, aimed at clarifying the taxonomic confusion between these genera and *Unguiculariopsis* is mainly based not on type studies but on original descriptions. The synonymies are not intended to be complete.

1. *Mollisiella aggregata* (Feltg.) Boud., Hist. Classif. Disc. Eur. p. 142, 1907.

≡ *Pezizella aggregata* Feltg., Vorst. Pilz-Flora Grossherz. Luxemb., Nachtr. 2: 39, 1901.

≡ *Unguiculella aggregata* (Feltg.) Höhn., Sitzungsber. Kaissrl. Akad. Wiss., Math.-Naturwiss. Kl., Abt. 1, 115: 1281, 1906.

Notes: This is one of Höhnel's original species of *Unguiculella*. Dennis (1949) and Raitviir (1970) have notes on this fungus.

2. *Mollisiella albido-lutea* (Feltg.) Boud., Hist. Classif. Disc. Eur. p. 142, 1907.

≡ *Pezizella albido-lutea* Feltg., Vorst. Pilz-Flora Grossherz. Luxemb., Nachtr. 2: 42, 1901.

≡ *Dasyscyphus albidoluteus* (Feltg.) Svrček, Česká Mykol. 33: 197, 1979.

Notes: According to Svrček (1979) this fungus has granulate hairs on the receptacle surface and lanceolate paraphyses. It is possibly a species of *Lachnum*.

3. *Mollisiella albido-rosea* (Rehm) Boud., Hist. Classif. Disc. Eur. p. 142, 1907.

≡ *Pezizella albido-rosea* Rehm in Rabenh. Krypt.-Fl. ed. 2, 1(3) [lief. 38]: 682, 1892.

≡ *Lachnum albidorosea* (Rehm) Nannf. in Sydow, Ann. Mycol. 34: 397, 1936.

Notes: Dennis (1949) illustrated and redescribed this fungus. It is a species of *Lachnum*.

4. *Mollisiella albo-nivea* (Rehm) Boud., Hist. Classif. Disc. Eur. p. 142, 1907 (ut '*albido-nivea*').

≡ *Pezizella albonivea* Rehm in Rabenh., Krypt.-Fl. ed. 2, 1(3) [lief. 54]: 1231, 1896.

Notes: This fungus has a hyaline excipulum, smooth receptacle surface, and J+ ascus iodine reaction. It is not an *Unguiculariopsis* species.

5. *Mollisiella albo-tincta* (Rehm) Boud., Hist. Classif. Disc. Eur. p. 142, 1907.

≡ *Pezizella albo-tincta* Rehm, Ann. Mycol. 2: 191, 1904.

Notes: The apothecia of this species are snow-white, sometimes white-yellowish, with excipular cells elongated and asci J+ in iodine reaction (Saccardo, 1906). Höhnel (1926) synonymized it with "*Helotium*" *herbarum* (Pers. : Fr.) Fr., but Dennis (1956) disagreed with his treatment.

6. *Mollisiella albula* (Phill.) Boud., Hist. Classif. Disc. Eur. p. 142, 1907.

≡ *Mollisia albula* Phill., Brit. Disc. p. 192, 1887.

Notes: According to the original author, the apothecia of this fungus are convex, white, shining, and smooth; the excipulum consists of elongated, cylindrical cells. Carpenter (1981) noted that it may be a species of *Hymenoscyphus*.

7. *Mollisiella anonyma* (Rehm) Rehm, Hedwigia 44: 9, 1905.

≡ *Pezizella anonyma* Rehm, Hedwigia 34: 165, 1895.

≡ *Pithyella anonyma* (Rehm) Korf & Zhuang, Mycotaxon 29: 4, 1987.

Notes: This is a species of *Pithyella* (Korf & Zhuang, 1987).

8. *Mollisiella apicalis* (Berk. & Br.) Sacc., Syll. Fung. 18: 64, 1906.

≡ *Peziza apicalis* Berk. & Br., J. Linn. Soc., Bot. 14: 106, 1873.

≡ *Pithyella apicalis* (Berk. & Br.) Korf & Zhuang, Mycotaxon 29: 4, 1987.

Notes: This is a species of *Pithyella*. Korf and Zhuang (1987) have a note on it.

9. *Mollisiella auricolor* (Rehm) Boud., Hist. Classif. Disc. Eur. p. 142, 1907.

≡ *Pezizella auricolor* Rehm in Rabenh., Krypt.-Fl. ed. 2, 1(3) [lief. 38]: 672, 1892.

Notes: The apothecia of this fungus are light in color, and asci J+ in iodine reaction, whereas species of *Unguiculariopsis* have dark apothecia and J– ascus iodine reaction.

10. *Mollisiella austriaca* Höhn., Ann. Mycol. 1: 369, 1903.

≡ *Pithyella austriaca* (Höhn.) Boud., Hist. Classif. Disc. Eur. p. 125, 1907.

Notes: I have examined the holotype. This fungus is the same as *Lachnellula theiodea* (Cooke & Ell.) Sacc. but the correct name for the fungus should be *Hyphodiscus theiodea* (Zhuang, 1988b).

11. *Mollisiella bresadolae* (Rehm) Boud. Hist. Classif. Disc. Eur. p. 142, 1907.

≡ *Pezizella bresadolae* Rehm in Raben., Krypt.-Fl. ed. 2, 1(3) [lief. 38]: 657, 1892.

Notes: The apothecia of this fungus are dirty cream-colored when fresh, yellowish brown upon drying, and smooth outside, whereas those of *Unguiculariopsis* are dark in color and furfuraceous outside.

12. *Mollisia* (subgen. *Mollisiella*) *bullii* (W. G. Smith) Phill., Brit. Disc. p. 194, 1887.

≡ *Peziza (Mollisia) bullii* W. G. Smith in Berk. & Br., Ann. Mag. Nat. Hist. ser. 4, 7: 433 (no. 1324), 1871.

≡ *Discocistella bullii* (W. G. Smith) Svrček, Česká Mykol. 16: 96, 1962.

Notes: The genus *Discocistella* was synonymized with *Dasyscyphus* by Korf (1973), and the latter is a later synonym of *Lachnum*, following the recent International Code of Botanical Nomenclature (Haines, 1984). This species may be either a species of *Lachnum* or of *Cistella*.

13. *Mollisiella caespiticia* (Karst.) Boud., Hist. Classif. Disc. Eur. p. 143, 1907.

≡ *Peziza caespiticia* Karst., Not. Sällsk. Fauna Fl. Fenn. Förh. 10: 159, 1869.

Notes: Nannfeldt (1932) had illustrated this species under the name of *Mollisia caespiticia* (Karst.) Karst. Dennis (1950) noted that sometimes cells in the excipulum give rise to hyaline, short, obtuse, thin-walled hairs, and that ascospores are fusoid with one end rounded and one pointed. Though this species occurs on ostioles of a pyrenomycete, its morphology does not match that of *Unguiculariopsis*.

14. *Mollisiella citrinula* (Karst.) Boud., Hist. Classif. Disc. Eur. p. 142, 1907.

≡ *Helotium citrinulum* Karst. Nat. Sällsk. Fauna Fl. Fenn. Förh. 11: 238, 1870.

Notes: Dennis (1956) placed this fungus under the genus *Calycellina*, but judging from his description and illustration, I think that it may be close to *Bisporella*.

15. *Mollisiella collina* (Speg.) Boud., Hist. Classif. Disc. Eur. p. 142, 1907.

≡ *Helotium collinum* Speg., Michelia 1: 473, 1879.

Notes: According to the original description, this species has grayish to slightly blue apothecia, smooth receptacle surface, J+ ascus iodine reaction, and cylindrical-fusoid to subclavate ascospores 10 x 1-1.5 µm. It may be a *Mollisia* species.

16. *Mollisia* (subgen. *Mollisiella*) *effugiens* (Rob. in Desm.) Phill., Brit. Disc. p. 196, 1887.

≡ *Peziza (Phialea) effugiens* Rob. in Desm., Ann. Sci. Nat. Bot. sér. 3, 20: 231, 1853.

≡ *Trichopeziza effugiens* (Rob. in Desm.) Le Gal, Rev. Mycol. (Paris) 4: 54, 1939.

Notes: This fungus has ivory-hyaline apothecia and fusiform ascospores 5-7 x 1 µm. It has no close relationship to *Unguiculariopsis*.

17. *Mollisiella elegans* (Saut.) Boud., Hist. Classif. Disc. Eur. p. 142, 1907.

≡ *Peziza elegans* Saut., Flora 24: 313, 1841.

Notes: The apothecia of this fungus are smooth, waxy, and flesh-colored (Saccardo, 1889). According to Keissler (1917) no type specimen has been found, and the species should be discarded ("Daher ist die Art einfach zu Streichen."). It is surely not a species of *Unguiculariopsis*.

18. *Mollisiella epithallina* (Phill. & Plow.) Boud., Hist. Classif. Disc. Eur. p. 142, 1907.

≡ *Peziza (Mollisia) epithallina* Phill. & Plow., Grevillea 6: 24, 1877. (ut '*epithalina*').

Notes: According Phillips (1887), the apothecia of this fungus are congregated, sessile, discoid, immarginate, pallid-white, and occur on the thallus of *Peltigera canina*. It is unlikely to be a species of *Unguiculariopsis*.

19. *Pithyella erythrostigma* (Berk. & Br.) Boud., Hist. Classif. Disc. Eur. p. 125, 1907.

≡ *Peziza erythrostigma* Berk. & Br., Ann. Mag. Nat. Hist., ser. 3, 18: 126, 1866.

Notes: This is a true *Pithyella*. Korf & Zhuang (1987) have noted and illustrated this fungus.

20. *Mollisiella fagiseda* Svrček, Česká Mykol. 31: 13, 1977.

Notes: The marginal hyphae of this fungus are cylindrical instead of having a swollen base and a fine, curved apex as in species of *Unguiculariopsis*.

21. *Mollisiella filicum* (Phill. in Phill. & Plowr.) Boud., Hist. Classif. Disc. Eur. p. 142, 1907.

≡ *Peziza (Mollisia) filicum* Phill. in Phill. & Plowr., Grevillea 13: 74, 1885.

≡ *Pezizella filicum* (Phill. in Phill. & Plowr.) Sacc., Syll. Fung. 8: 281. 1889.

Notes: This fungus was redescribed and illustrated by Bøhler as *Pezizella filicum* (Bøhler, 1974). It is unlikely to be either a synonym of *Pezizella campanuliformis* (Fuckel) Dennis [≡ *Hymenoscyphus campanuliformis* (Fuckel) Rasch.] as treated by Dennis (1956) or a synonym of *Allophylaria chrysostigma* (Fr.) Nannf. [≡ *Psilachnum chrysostigmum* (Fr.) Raitv.] as treated by Nannfeldt (1939).

22. *Mollisiella fusco-sanguinea* (Rehm) Boud. Hist. Classif. Disc. Eur. p. 142, 1907.

≡ *Pezizella fuscosanguinea* Rehm, Disc. in Rabenh. Krypt.-Fl. ed. 2, [lief. 38] : 675, 1892.

Notes: The original description indicates that this fungus has a brownish yellow receptacle, pale red hymenium, and fibrous margin with blunt cells. It is not a species of *Unguiculariopsis*.

23. *Mollisiella graminea* (Karst.) Boud., Hist. Classif. Disc. Eur. p. 143, 1907.

≡ *Peziza graminea* Karst., Fung. Fenn. Exs. no. 747, 1868.

Notes: Dennis (1950) described the asci of this species as blue in Melzer's reagent, and ascospores fusoid, 3-septate. Species of *Unguiculariopsis* have a J– ascus iodine reaction, unicellular, spherical to ellipsoid ascospores, and characteristic hairs.

24. *Mollisiella granulosella* (Karst.) Boud., Hist. Classif. Disc. Eur. p. 142, 1907.

≡ *Peziza granulosella* Karst., Not. Sällsk. Fauna Fl. Förh. 10: 180, 1869.

≡ *Cistella granulosella* (Karst.) Nannf., Nova Acata Regiae Soc. Sci. Upsal. 4, 8(2): 270, 1932.

Notes: This is a species of *Cistella*. Nannfeldt (1932) illustrated this species.

25. *Mollisiella helotioides* (Starb.) Boud. Hist. Classif. Disc. Eur. p. 143, 1907.

≡ *Pezizella* (*Ctenoscypha*) *helotioides* Starb., Bih. Kongl. Svenska Vetensk.-Akad. Handl. 21(III, 5): 32, 1895.

Notes: The apothecia of this fungus are yellow, excipulum of textura prismatica, and ascospores elongated fusoid, 10-14 x 1.5-2 µm. It is not related to *Unguiculariopsis*.

26. *Mollisia* (subgen. *Mollisiella*) *hydnicola* (Berk. & Br.) Phill., Brit. Disc. p. 194, 1887.

≡ *Peziza hydnicola* Berk. & Br., Ann. Mag. Nat. Hist., ser. 4, 7: 434, 1871.

≡ *Mollisiella hydnicola* (Berk. & Br.) Sacc., Syll. Fung. 18: 64, 1906.

≡ *Pithyella hydnicola* (Berk. & Br.) Boud., Hist. Classif. Disc. Eur. p. 125, 1907.

≡ *Claussenomyces hydnicola* (Berk. & Br.) Korf & Zhuang, Mycotaxon 29: 8, 1987.

Notes: This fungus is a species of *Claussenomyces* and has been discussed by Korf & Zhuang (1987).

27. *Pithyella hypnina* (Quélet) Boud., Icones Mycol. p. [4], 1904.

≡ *Mollisia hypnina* Quél., Bull. Soc. Bot. France 25: 291: 1879.

Notes: This is the type species of the genus *Pithyella* (Boudier, 1885).

28. *Pithyella hypnorum* (Fr.: Fr.) Boud., Hist. Classif. Disc. Eur. p. 125, 1907.

≡ *Peziza hypnorum* Fr. : Fr., Syst. Mycol. 2: 149, 1822.

Notes: This is a lost species, as has been noted by Korf & Zhuang (1987).

29. *Mollisiella infixa* (Wallr.) Boud., Hist. Classif. Disc. Eur. p. 142, 1907.

≡ *Peziza infixa* Wallr., Fl. Crypt. Germ. 4: 470 (no. 2504), 1833.

Notes: According to Saccardo (1889), the apothecia of this fungus are white, subtremelloid when fresh, and golden yellow upon drying. It is unlikely to be a species of *Unguiculariopsis*.

30. *Pithyella jenkinsii* (Sherw. & Korf) Korf & Zhuang, Mycotaxon 29: 7, 1987.

≡ *Helotiopsis jenkinsii* Sherw. & Korf, Mycotaxon 3: 321, 1976.

Notes: This is a true *Pithyella* (Korf & Zhuang, 1987).

31. *Mollisiella lilacina* (Sacc.) Boud., Hist. Classif. Disc. Eur. p. 142, 1907.

≡ *Elevela lilacea* Wulf. in Jacq. : Fr., Coll. Bot. Chem. Hist. Nat. 1: 347, 1786 (corr. '*lilacina*', Fries, Syst. Mycol. 2: 140, 1822).

≡ *Niptera lilacina* (Wulf.) Sacc., Atti Accad. Sci. Veneto-Trentino-Istriana, Padova, ser. 4, #70, 1875.

Notes: The apothecia of this fungus are waxy, smooth, and beautifully lilac when fresh, pale lilac when dry; and quite different from those of *Unguiculariopsis*. Boudier (1907) mistakenly treated Saccardo as the original author.

32. *Mollisia* (subgen. *Mollisiella*) *lurida* (Pers.) Phill., Brit. Disc. p. 197, 1887.

≡ *Peziza lurida* Pers., Syn. Meth. Fung. p. 666, 1801.

Notes: This species has linear ascospores, which have never been found in *Unguiculariopsis*.

33. *Mollisiella luteo-fuscescens* (Feltg.) Boud., Hist. Classif. Disc. Eur. p. 142, 1907.

≡ *Mollisia luteo-fuscescens* Feltg., Vorst. Pilz-Flora Grossherz. Luxemb., Nachtr. p. 26, 1903.

Notes: According the original author, the apothecia of this fungus have yellowish brown receptacle, yellow hymenium, and fusoid ascospores with blunt ends, measuring 6.5-7.5 x 1.5 µm. I found no indication that this could be a species of *Unguiculariopsis*. Höhnel (1906) noted that the type collection is a badly preserved, old specimen of *Pezizella teucrii*.

34. *Mollisia* (subgen. *Mollisiella*) *mali* (Rehm) Phill., Brit. Disc. p. 194, 1887.

≡ *Pezizella mali* Rehm, Ascom. Exs. no. 460, 1878.

≡ *Cistella mali* (Rehm) Nannf., Nova Acta Regiae Soc. Sci. Upsal. 4, 8(23): 270, 1932.

Notes: This is a species of *Cistella*.

35. *Mollisiella minima* (Fr.) Boud., Hist. Classif. Disc. Eur. p. 142, 1907.

≡ *Peziza minima* Fr., Elench. Fung. 2: 13, 1830.

Notes: According to the original description, the apothecia of this species are firm, reddish brown, or approaching white, and on *Hydnum farinaceum*.

36. *Mollisiella minutissima* (Karst. & Starb.) Boud., Hist. Classif. Disc. Eur. p. 142, 1907.

≡ *Helotium minutissimum* Karst. & Starb., Hedwigia 26: 124, 1887.

Notes: According to the original description, the apothecia are naked, light in color when fresh, pale brown when dry; and occur on leaves of *Comarum palustre*. This fungus is not a species of *Unguiculariopsis*.

37. *Mollisiella myricae* (Rehm) Boud. Hist. Classif. Disc. Eur. p. 142, 1907.

≡ *Pezizella myricae* Rehm in Raben., Krypt.-Fl. ed. 2, 1(3) p. 665, 1892.

Notes: According to the original author, asci of this fungus are J+ in iodine reaction, and ascospores are fusoid. It occurs on the upper side of dry leaves of *Myrica cerifera*. This fungus is not a species of *Unguiculariopsis*.

38. *Mollisiella myriostylidis* Rehm, Hedwigia 6: 301, 1892.

Notes: This is a species of *Parencoelia* (Zhuang, 1988a).

39. *Mollisiella nectriella* (Karst.) Boud., Hist. Classif. Disc. Eur. p. 142, 1907.

≡ *Helotium nectriellum* Karst., Hedwigia 23: 88, 1884.

Notes: The apothecia of this fungus are strongly convex, ascus J+ in iodine reaction, and excipular cells of textura prismatica. Dennis (1956) placed this species under *Calycellina*.

40. *Mollisiella nemophila* (Sacc.) Boud., Hist. Classif. Disc. Eur. p. 143, 1907 (as '*nemaphila*').

≡ *Niptera nemophila* Sacc., Fung. Ital. fig. 1382, 1883.

Notes: According to Saccardo (1889), the ascospores of this fungus are cylindrical to subfusoid and 1-septate, which has not been found in any species of *Unguiculariopsis*.

41. *Mollisiella obscurella* Boud., Hist. Classif. Disc. Eur. p. 142, 1907.

Notes: Saccardo and Trotter (1913) transferred this fungus to *Mollisia*. It has subglobose excipular cells, but neither hairs nor hyphal protrusions were noticed. Boudier's illustration (Boudier, Icones Mycol. pl. 556, 1906) shows that it may be a species of *Mollisia*.

42. *Mollisiella olivaceo-brunnea* Grelet, Rev. Mycol. (Paris) 19: 147, 1954.

Notes: According to the original author, the marginal cells of the apothecium are elongated with an obtuse apex. It is not a species of *Unguiculariopsis*.

43. *Mollisiella pallens* Boud., Hist. Classif. Disc. Eur. p. 142, 1907.

Notes: This is obviously not a species of *Unguiculariopsis*. Boudier's illustration (Boudier, Icones Mycol. pl. 557, 1906) shows that it may be a species of *Mollisia*.

44. *Mollisiella pallida* (Feltg.) Boud., Hist. Classif. Disc. Eur. p. 143, 1907.

≡ *Mollisia pallida* Feltg., Vorst. Pilz-Flora Grossherz. Luxemb., Nachtr. 3: 21, 1903.

Notes: This is possibly a *Mollisia* species with apothecia brown at base, pale in center, and ascospores fusoid. Höhnel (1906) examined the type, which was very poor and immature, and suggested discarding the name.

45. *Mollisia perparvula* (Karst.) Karst., Bidrag Kännedom Finlands Natur Folk 19: 191, 1871.

≡ *Peziza perparvula* Karst., Not. Sällsk. Fauna Fl. Fenn. Förh. n. s. 10: 162, 1869.

Notes: This is the type species of *Mollisiella* Boudier (1885). I have examined the type specimen. It is a *Mollisia* with a very short stalk.

46. *Mollisia* (subgen. *Mollisiella*) *pineti* (Batsch : Fr.) Phill., Brit. Disc. p. 195, 1887.

≡ *Peziza pineti* Batsch : Fr., Elench. Fung. 1: 201, 1786.

≡ *Pseudohelotium pineti* (Bastch : Fr.) Fuckel, Jahrb. Nassauischen Vereins Naturk. 23-24: 298, 1870.

Notes: This is the type species of the genus *Pseudohelotium* (Clements & Shear, 1931). Dennis (1956) redescribed and illustrated this fungus, and Carpenter (1981) has a note on it.

47. *Mollisiella plicatula* (Rehm) Boud., Hist. Classif. Disc. Eur. p. 142, 1907.

≡ *Pezizella plicatula* Rehm in Raben., Krypt.-Fl. ed. 2, 1(3) p. 676, 1892.

Notes: The apothecia of this fungus are light-colored, with the outside folded (Saccardo, 1889). It is not a species of *Unguiculariopsis*.

48. *Mollisiella pruinosa* (Wallr.) Boud., Hist. Classif. Disc. Eur. p. 142, 1907.

≡ *Peziza pruinosa* Wallr., Fl. Crypt. Germ. 4: 487 (no. 2564), 1833.

Notes: Saccardo (1889) described this species under *Pseudohelotium*. The apothecia are fleshy, membrane-like, the receptacle surface slightly mealy. No feature indicates that it is an *Unguiculariopsis* species.

49. *Mollisiella pudica* (Rehm) Boud., Hist. Classif. Disc. Eur. p. 143, 1907.

≡ *Pezizella pudica* Rehm in Raben., Krypt.-Fl. ed. 2, 1(3) [lief. 37 & 38]: 656-657, 1892 (July & September).

Notes: The asci of this fungus are J+ in iodine reaction, ascospores elongate-fusoid. It is not a species of *Unguiculariopsis*.

It is difficult to decide on the correct date of publication of Rehm's species, since the name and part of the description appeared in July, 1892, and the rest of the description in September, 1892.

50. *Mollisiella rehmii* (Sacc.) Boud., Hist. Classif. Disc. Eur. p. 142, 1907.

≡ *Pezizella aconiti* Rehm, Ber. Naturhist. Vereins Augsburg 26: 43, 1881.

≡ *Pezizella rehmii* Sacc., Syll. Fung. 8: 282, 1889; non *Pezizella aconiti* (Saut.) Sacc., nom. superfl.

≡ *Dasyscyphus aconiti* (Rehm) Dennis, Persoonia 3: 31, 1964.

≡ **Lachnum aconiti** (Rehm) Zhuang, **comb. nov.**

Notes: This a species of *Lachnum*. Dennis (1964) has illustrated and redescribed this fungus.

51. *Mollisiella sclerotinioides* (Rehm) Boud., Hist. Classif. Disc. Eur. p. 142, 1907.

≡ *Pezizella sclerotinioides* Rehm in Raben., Krypt.-Fl. ed. 2, 1(3) p. 667, 1892.

Notes: According to the original author, the apothecia of this fungus are whitish in color, and asci are J+ in iodine reaction.

52. *Mollisiella separabilis* (Karst.) Boud., Hist. Classif. Disc. Eur. p. 142, 1907.

≡ *Helotium separabile* Karst., Mycol. Fenn. p. 118, 1871.

≡ *Hymenoscyphus separabilis* (Karst.) Dennis, Persoonia 3: 77, 1964.

Notes: According to Dennis (1964), this fungus is a species of *Hymenoscyphus* and has cream-colored apothecia, hyaline excipular cells, J+ ascus iodine reaction, and fusoid ascospores.

53. *Mollisia* (subgen. *Mollisiella*) *stramineum* (Berk. & Br.) Phill., Brit. Disc. p. 196, 1887.

≡ *Peziza stramineum* Berk. & Br., Ann. Mag. Nat. Hist. ser. 2, 7: 182, 1851.

≡ *Crocicreas stramineum* (Berk. & Br.) Carp., Brittonia 32: 271, 1980.

Notes: This is a species of *Crocicreas*.

54. *Mollisiella subtilissima* (Schroet.) Boud., Hist. Classif. Disc. Eur. p. 142, 1907.

≡ *Hymenoscypha subtilissima* Schroet., Pilze Schles. 3(1): 70, 1893.

Notes: This species is excluded from *Unguiculariopsis* because of its dirty white, translucent apothecia and fusoid ascospores. I did not examine any specimen under this name.

55. *Mollisiella tetraspora* (Feltg.) Boud., Hist. Classif. Disc. Eur. p. 142, 1907.

≡ *Pezizella tetraspora* Feltg., Vorst. Pilz-Flora Grossherz. Luxemb., Nachtr. 3: 54, 1903.
= *Hyaloscypha lachnobrachya* (Desm.) Nannf., Nova Acta Regiae Soc. Sci. Upsal. 4, 8(2): 273, 1932.

Notes: This species was listed as one of the synonyms of *Hyaloscypha lachnobrachya* (Desm.) Nannfeldt by Nannfeldt (1932).

56. *Mollisiella teucrii* (Fuckel) Boud., Hist. Classif. Disc. Eur. p. 142, 1907.

≡ *Niptera teucrii* Fuckel, Jahrb. Nassauischen Vereins Naturk. 25-26: 335, 1871.

Notes: This species has pale to yellowish apothecia and cylindrical, slightly curved ascospores. It is not related to *Unguiculariopsis*.

57. *Mollisiella teucrii* (Fuckel) Boud. var. *lunariae* (Allesch.) Boud., Hist. Classif. Disc. Eur. p. 142, 1907.

≡ *Mollisia teucrii* (Fuckel) Rehm forma *lunariae* Allesch., Ber. Bot. Vereines Landshut 15: 67, 1898.

Notes: The ascospores of this species are bacteriform and about 8-12 x 1-1.5 µm. It is not a species of *Unguiculariopsis*.

58. *Mollisiella trinitensis* Cash, J. Wash. Acad. Sci. 48: 256, 1958.

Notes: This is a species of *Parencoelia* (Zhuang, 1988a).

59. *Mollisiella umbonata* (Pers.) Boud., Hist. Classif. Disc. Eur. p. 143, 1907.

≡ *Peziza umbonata* Pers., Syn. Fung. p. 669, 1801.

Notes: According to the original description, the apothecia of this fungus are white-bluish grey, subgelatinized, and with smooth receptacle surface. This is not a species of *Unguiculariopsis*.

60. *Mollisiella umbonata* (Pers.) Boud. var. *amenticola* (Sacc.) Boud., Hist. Classif. Disc. p. 143, 1907.

≡ *Mollisia umbonata* (Pers.) Sacc. var. *amenticola* Sacc., Syll. Fung. 8: 335, 1889.

Notes: The ascospores of this fungus are cylindrical and somewhat curved, a feature lacking in *Unguiculariopsis*.

61. *Mollisia* (subgen. *Mollisiella*) *versicolor* (Desm.) Phill., Brit. Disc. p. 195, 1887.

≡ *Peziza versicolor* Desm., Ann. Sci. Nat. Bot. sér. 3, 20: 238, 1853.
= *Psilachnum chrysostigmum* (Fr.) Raitv., Scripta Mycol. 1: 104, 1970.

Notes: According to Carpenter (1981), this species is a synonym of *Psilachnum chrysostigmum* (Fr.) Raitv.

62. *Mollisiella viridiflavescens* (Rehm) Boud., Hist. Classif. Disc. Eur. p. 142, 1907.

≡ *Mollisia viridiflavescens* Rehm in Sydow, Mycoth. March. no. 1746, 1887.

≡ *Phialina viridiflavescens* (Rehm) Raitv., Folia Cryptog. Eston. 9: 1, 1977.

Notes: This species has green-yellow apothecia when dry, and ascospores 4-5 x 1-1.5 μm. It was transferred to *Cistella* by Nannfeldt (1932) but was illustrated without granules on the apex of short hairs. Raitviir transferred it to *Phialina*, which has been treated as a synonym of *Calycellina* by Korf (1973).

63. *Mollisiella xylita* (Karst.) Boud., Hist. Classif. Disc. Eur. p. 142, 1907.

≡ *Peziza xylita* Karst., Fung. Fenn. Exs. 645, 1867.

≡ *Cistella xylita* (Karst.) Nannf., Nova Acta Regiae Soc. Sci. Upsal. 4, 8(2): 271, 1932.

Notes: Nannfeldt (1932) described and illustrated this fungus. It has short, granulate hairs and is a species of *Cistella*.

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New names and the page numbers on which such new taxa are proposed are in **boldface**.

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THE GENUS PARENCOELIA (LEOTIACEAE, ENCOELIOIDEAE)

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The genus *Parencoelia* was established by Petrak (1950) to include a single species, *P. andina* Petrak, which occurs on stromata of *Phyllachora* species and other fungi on different host plants. The genus remained monotypic until this study and has probably not been examined by any other mycologists since it was published. Korf (1973) noted under the genus *Unguiculariopsis* in his chapter on Discomycetes and Tuberales that "*Parencoelia*, in which no hairs are reported, may be related." During my study of the genus *Unguiculariopsis* (Zhuang, 1988), five known specimens of *Parencoelia* were borrowed and examined. My observations indicate that both *Unguiculariopsis* and *Parencoelia* are fungicolous, related in certain respects, but not congeneric. *Parencoelia* differs from *Unguiculariopsis* in lack of characteristic hairs which have a swollen base and a fine, curved apex, in possessing thin-walled instead of thick-walled excipular cells, and in possessing turbinate to discoid apothecia. *Parencoelia* differs also in being clearly hyperparasitic for its host fungi fail to form mature asci, in contrast to *Unguiculariopsis* where normal asci are produced in the host fungus.

Parencoelia was described in great detail and assigned to the subfamily Encoelioideae when Petrak (1950) published the generic name. In his paper, not only did he thoroughly describe the morphology and ontogenesis of the type specimen of *P. andina*, but he also described four other specimens very carefully. He indicated that these four collections are somewhat or even strongly different from the type and that it was not clear whether they are different forms of the same species or closely related but distinct species (Petrak, 1950). The apothecia of these specimens are on stromata of *Phyllachora* and of other fungi, but none is on the same species of host fungus, and none is on the same host plant. My examinations have shown that the five specimens are congeneric and structurally similar to each other. Two of them, the holotype of *P. andina* and W-16795, have ovoid to broadly ellipsoid ascospores and occur on stromata of *Phyllachora*; two others, W-16885 and W-20167, have large, ellipsoid spores and invade other ascomycetes; and one (W-20337) has spherical ascospores and is also on *Phyllachora*. Petrak mistakenly reported that both ovoid and spherical ascospores were present in the same apothecium in the holotype specimen. In fact, the ascospores of that specimen have a very small length/breadth ratio, and are not arranged in a regular pattern within an ascus; when the end of an ovoid ascospore faces our eyes, it appears spherical.

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[1] Based in part on a Ph. D. thesis presented to the Graduate School, Cornell University. Present address: Department of Mycology, Institute of Microbiology, Academia Sinica, Beijing, People's Republic of China.

Cenangium biparasiticum Pat., a parasite on *Cocconia* sp., was also studied. My examination reveals that it is a species of *Parencoelia*. It differs from *P. andina* in ellipsoid, much larger ascospores, spore guttulation, large asci, and host fungus. A new combination needs to be made. W-16885 and W-20167, which were treated as paratypes of *P. andina* by Petrak (1950), are very similar to *C. biparasiticum* in excipular structure, length of ascospores and of asci, and probably in their closely related bitunicate host fungi. Although their spores are not as broad as those of *C. biparasiticum*, I tentatively place them under this species in order to exclude these two collections from *P. andina*. Further studies are needed when more collections become available and the host fungi can clearly be identified.

The spherical-spored fungus is undoubtedly congeneric with the typical *Parencoelia andina*, but it is not the same. It is on *Phyllachora pichinchae* on the leaves of *Acalypha* sp., has a coelomycete anamorph, and is surely conspecific with *Mollisiella myriostylidis* Rehm, which occurs on *Phyllachora* sp. on the leaves of *Myriostylis* sp. and was described much earlier. The type localities of the spherical spored "*P. andina*" and of *M. myriostylidis* are very close (Rehm, 1892; Petrak, 1950). The same anamorph is also found in the isotypes of *M. myriostylidis*. The genus *Mollisiella*, in which Rehm put his species, was raised from one of Phillips's subgenera of *Mollisia*. The correct name of *Mollisiella* (Phill.) Rehm is *Unguiculariopsis*. *M. myriostylidis* cannot be a species of *Unguiculariopsis*, but it is a *Parencoelia*. A new combination should be made in *Parencoelia*.

Phaeofabraea, which has been placed in the Encoelioideae by Pfister (1977), may be closely related to *Parencoelia*. They are similar in being fungicolous, in excipular structure, and in production of crystals in the excipulum. *Parencoelia* can be distinguished from *Phaeofabraea* by the lighter apothecial tissues and ascospores that are hyaline instead of dark brown with a hyaline band circling the spore (Rehm, 1909; Petrak, 1950; Pfister, 1977).

Even though the original authors of *Parencoelia andina, Cenangium biparasiticum,* and *Mollisiella myriostylidis* gave detailed morphological

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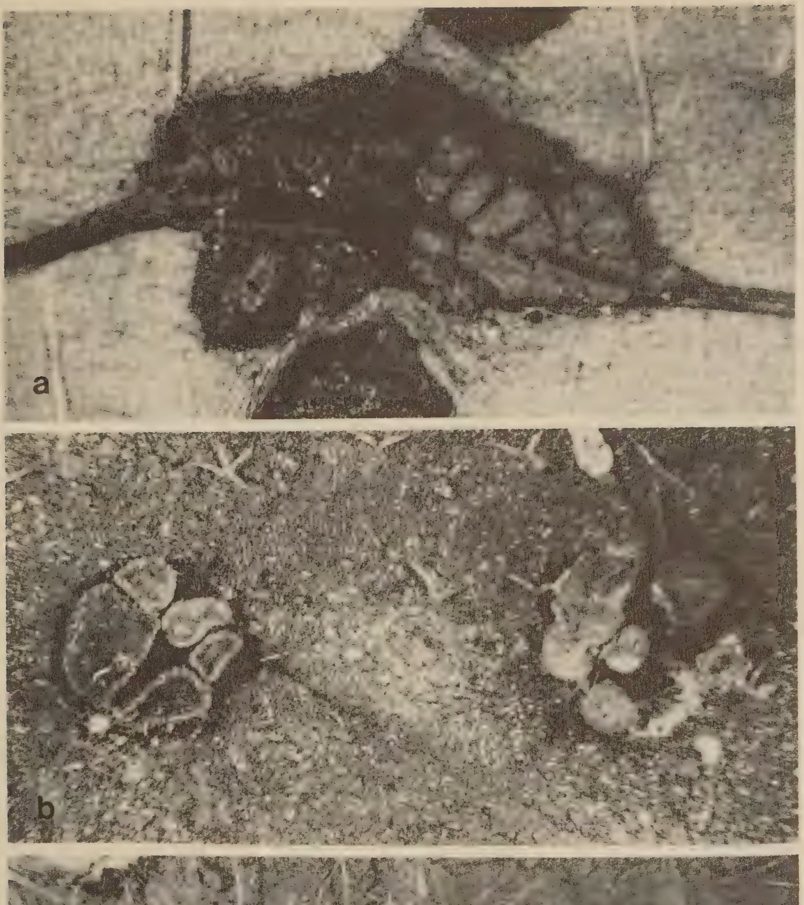
FIG. 1. *Parencoelia* species and their hosts: **a.** *P. andina* on *Phyllachora* sp. (from holotype), **b.** *P. biparasitica* on *Cocconia* sp. (from holotype), **c.** *P. myriostylidis* on *Phyllachora* sp. (from isotype in ZT); all x 17.5.


a
b
c

information, I redescribe and illustrate the three taxa in this paper to give a better understanding of the genus *Parencoelia*.

Parencoelia Petrak, Sydowia 4: 349, 1950, emend.

Apothecia gregarious, discoid, flat or turbinate, sessile to subsessile; hymenium beige to brown; receptacle surface furfuraceous. Ectal excipulum of textura globulosa to textura angularis; cells brown to light brown, thin-walled; outside with short hyphal protrusions, marginal hyphae more or less parallel. Medullary excipulum of textura intricata to textura angularis; hyphae light brown to subhyaline. Crystals often present in excipular tissues. Asci inoperculate, 8-spored, less commonly 4-spored, subcylindrical to clavate, J– to faintly J+ in Melzer's reagent with KOH pretreatment. Ascospores spherical, broadly ellipsoid, or ellipsoid, hyaline, sometimes brownish at maturity, guttulate, unicellular. Paraphyses filiform.

On other fungi.

An acervular anamorph is known only in *Parencoelia myriostylidis*.

Type: *Parencoelia andina* Petrak.

Parencoelia andina Petrak, Sydowia 4: 350, 1950, emend. (Figs. 1a, 2)

Apothecia gregarious, discoid to flat when dry, flat or convex when fresh, sessile, subsessile to very shortly stipitate, 0.2-1.0 mm in diam when dry, 0.3-1.0 mm, rarely up to 1.5 mm, in diam when fresh; hymenium brown, dark brown, or vinaceous brown when dry, grey or bright olive-green when fresh; receptacle usually light brown to brown when dry, surface furfuraceous. Ectal excipulum of textura globulosa to textura angularis, 25-55 µm thick; cells brown to light brown, thin-walled, isodiametric to ovoid, 5.5-11.0 µm in diam; with short hyphal protrusions extending toward outside, margin with hyphae more or less parallel. Medullary excipulum of textura angularis mixed with textura intricata, not clearly distinguished from ectal excipulum; tissues light brown, with numerous pale yellow crystals. Asci 8-spored, subclavate, J+ in holotype (or J– in paratype) in Melzer's reagent with 10% KOH pretreatment, 70-90 x 7.5-8.8 µm, with a crozier at base. Ascospores uniseriate, ovoid to broadly ellipsoid, hyaline, unicellular, uniguttulate, 5.1-6.6 x 3.5-4.8 µm, sometimes with a refractive body inside the spores. Paraphyses filiform, 1.5-2.0 µm wide, equal to or slightly exceeding asci.

HABITAT: On stromata of *Phyllachora* species.

SPECIMENS EXAMINED: **Ecuador**: On stromata of *Phyllachora ulei* on leaves of *Dioscorea trifida*, Prov. Pichincha, Mindo, H. Sydow, 4. XI. 1937, W-07295 (Reliquiae Petrakianae 482) (holotype); on stromata of

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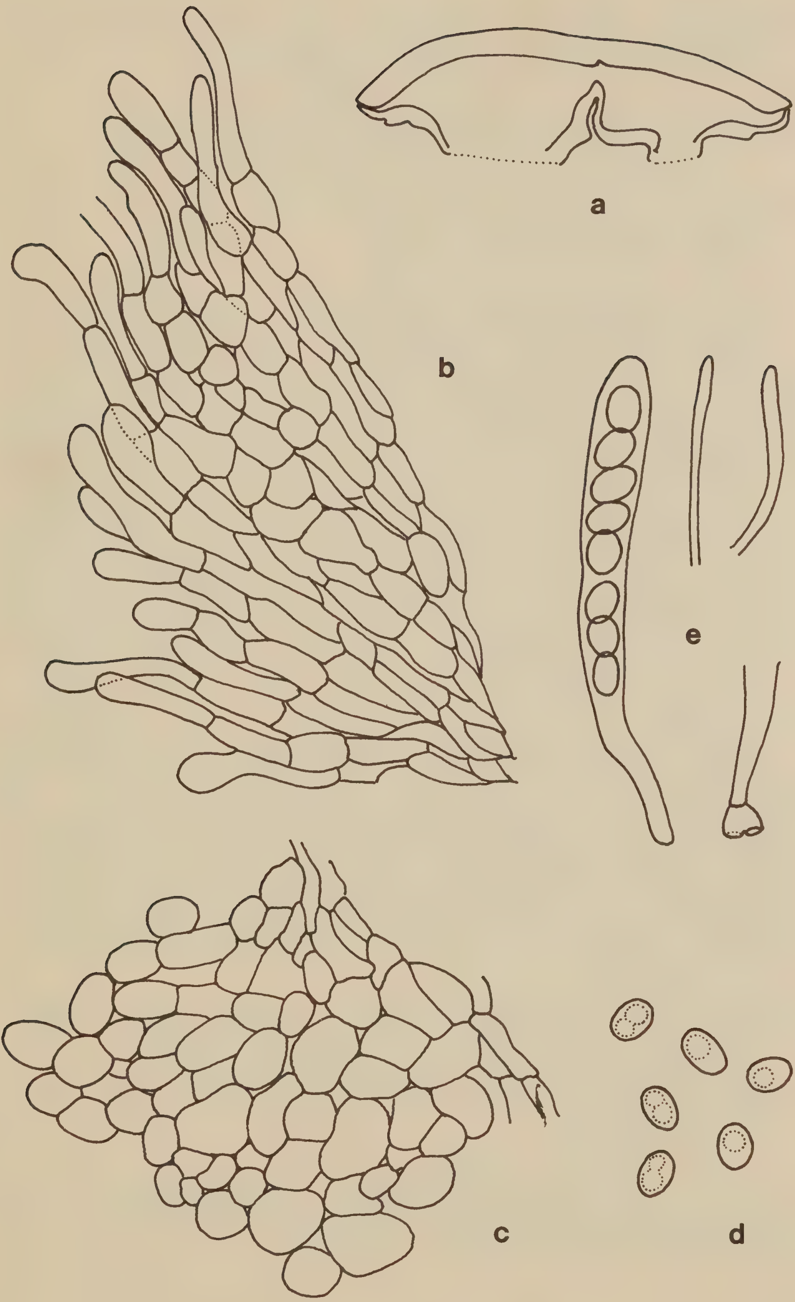
FIG. 2. *Parencoelia andina* (holotype): **a**. shape of apothecia, from top to bottom showing hymenium, medullary excipulum and ectal excipulum, **b**. structure of excipulum at margin, **c**. structure of excipulum at flank, **d**. ascospores, **e**. ascus, ascus base and paraphysis apices; **a** x 38, **b-e** x 1000.


a
b
e
c
d

Phyllachora massinii on leaves of *Brunellia comocladiaefolia*, Prov. Tungurahua: Hacienda San Antonio bei Banos, H. Sydow, 17. XII. 1937, W-16795 (Petrak 41350) (paratype, "Forma 3").

Parencoelia biparasitica (Pat.) Zhuang, **comb. nov.** (Figs. 1b, 3)

≡ *Cenangium biparasiticum* Pat., Bull. Soc. Mycol. France 11: 219, 1895.

MISAPPLICATION: *Parencoelia andina* Petrak, Sydowia 4: 350, 1950, pro parte ("Forma 1, 2").

Apothecia gregarious, discoid, sessile, 0.5-1.0 mm in diam; hymenium dark brown to fuscous when dry; receptacle lighter than hymenium or "Cinnamon-Drab (Ridgway)" when dry (according to notes by W. L. White), surface furfuraceous to downy. Ectal excipulum of textura angularis; cells light brown, thin-walled, isodiametric, ovoid to ellipsoid, 5.0-9.5 in diam; margin with hyphae more or less parallel, with numerous pale yellow crystals. Medullary excipulum of textura angularis to textura intricata, not clearly distinguished from ectal excipulum; cell walls light brown, with numerous pale yellow crystals. Subhymenium indistinguishable. Asci 4- to 8-spored, clavate with an elongated, narrow base, J– in Melzer's reagent with 10% KOH pretreatment, 73-132 x (9-) 10-13 µm. Ascospores irregularly uniseriate, broadly ellipsoid with blunt ends, many guttules of different size with 1-2 larger, (8.0-)8.5-12.4 x (4.4-)5.1-6.9 µm. Paraphyses cylindrical, 2 µm wide, slightly to obviously exceeding asci.

HABITAT: On pseudothecia of *Cocconia* sp. and stromata of *Phyllachora* sp.

SPECIMENS EXAMINED: **Ecuador**: On pseudothecia of *Cocconia* sp. (as Phymatosphaeriaceae) on a leaf of an unidentified tree, San Jorge, Lagerh[eim], VII. 1892, FH-Patouillard Herb. (holotype of *Cenangium biparasiticum*); on stromata of a Polystomellaceous fungus on leaves of an unidentified tree, Prov. Pichincha: Mindo, H. Sydow, 1. XI. 1937, W-16835 (Petrak 41390) (paratype of *Parencoelia andina*); on stromata of ?*Phyllachora* sp. on leaves of an unidentified tree, Prov. Pichincha: Mindo, H. Sydow, 2. XI. 1937, W-20167 (Petrak 39145) (paratype of *Parencoelia andina*).

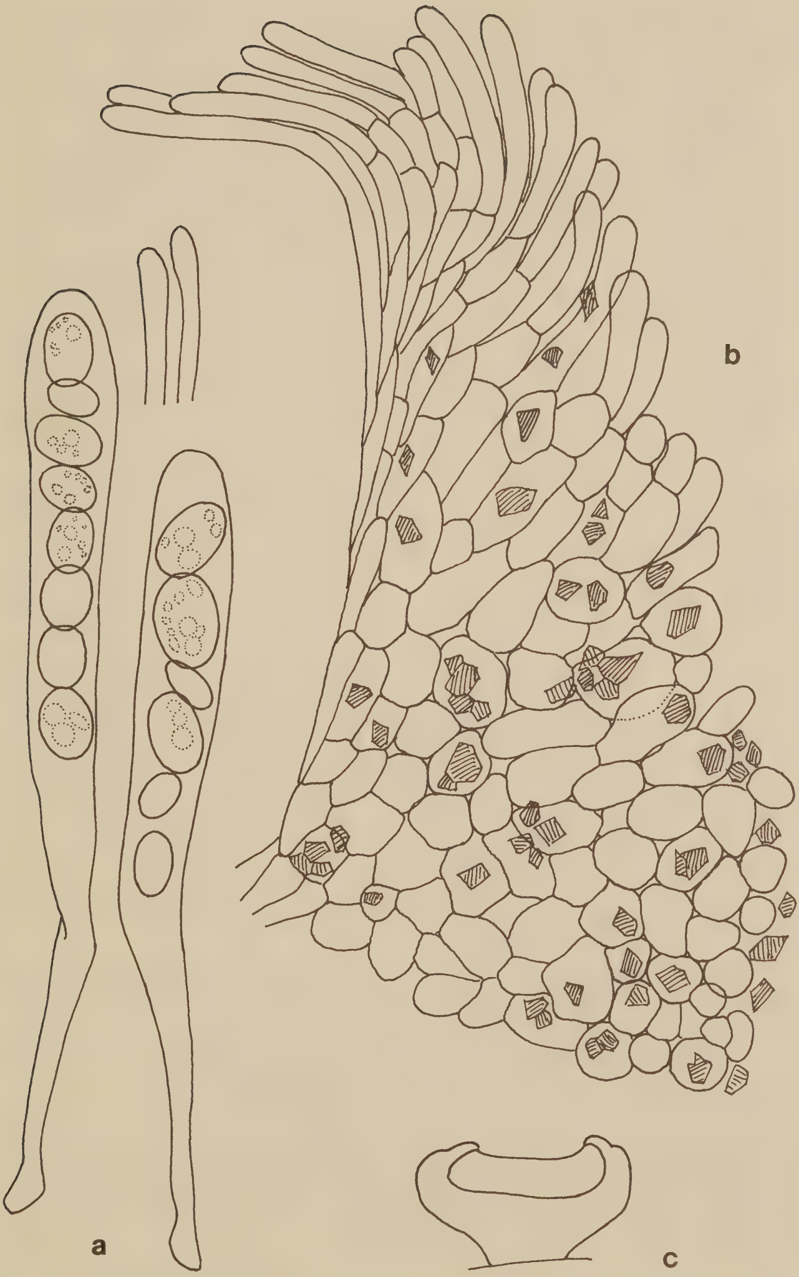
Parencoelia myriostylidis (Rehm) Zhuang, **comb. nov.** (Figs. 1c, 4, 5)

≡ *Mollisiella myriostylidis* Rehm, Hedwigia 6: 301, 1892.

= *Mollisiella trinitensis* Cash, J. Wash. Acad. Sci. 48: 256, 1958.

MISAPPLICATION: *Parencoelia andina* Petrak, Sydowia 4: 350, 1950, pro parte ("Forma 4").

FIG 3. *Parencoelia biparasitica* (holotype): **a**. paraphysis apices and asci with ascospores, **b**. structure of excipulum, **c**. shape of apothecium, from top to bottom showing hymenium and excipulum; **a**, **b** x 1000, **c** x 50.


b
a
c

Apothecia gregarious, turbinate to flat, sessile to subsessile, 0.3-0.8 mm in diam when dry; hymenium beige to brown when dry; receptacle lighter than hymenium or somewhat whitish, surface furfuraceous to downy. Pale yellow crystals covering the outer surface, at junction of medullary and ectal excipula at flanks, and numerous at the base of apothecium, crystals partially dissolving in KOH and gradually dissolving in cotton blue-lactic acid. Ectal excipulum of textura angularis, (13-)19-47 µm thick; cells subspherical to ovoid, brown, thin-walled, 5.0-15.0 µm in diam, sometimes with short hairs outside, hyphoid at margin. Medullary excipulum of textura intricata, very thick; hyphae pale brown to subhyaline, loosely interwoven. Asci 8-spored, subcylindrical, J– in Melzer's reagent with 10% KOH pretreatment, 65-80 x 6.5-6.8 µm, with crozier at base. Ascospores uniseriate, spherical to subspherical, unicellular, uniguttulate, hyaline and thick-walled within the ascus, with a refractive, equatorial plate which disappears after KOH treatment, a few slightly brown when found outside the ascus, 4.0-5.1 µm in diam. Paraphyses filiform, 1.5 µm wide, not exceeding asci.

Anamorph (unnamed): Conidiomata acervular, on the other side of the stroma which gives rise to the apothecia, epiphyllous, subepidermal, circulate, ca. 200 µm in diam (300-600 µm according to Petrak), or irregularly elongated. Conidiophore absent. Conidiogenous cells holoblastic, subcylindrical, subhyaline, parallel at base of acervulus. Conidia shortly cylindrical, with a blunt apex and a broad truncate base, hyaline, 4.2-4.8 x 2.8-3.5 µm (4-5.5 x 2.5-3 µm according to Petrak).

HABITAT: On stromata of *Phyllachora pichinchae* on leaves of *Acalypha* sp., stromata of *Phyllachora* sp. on leaves of *Myriostylis* sp., and leaf of *Persea americana*, probably on the fungus causing a leaf spot.

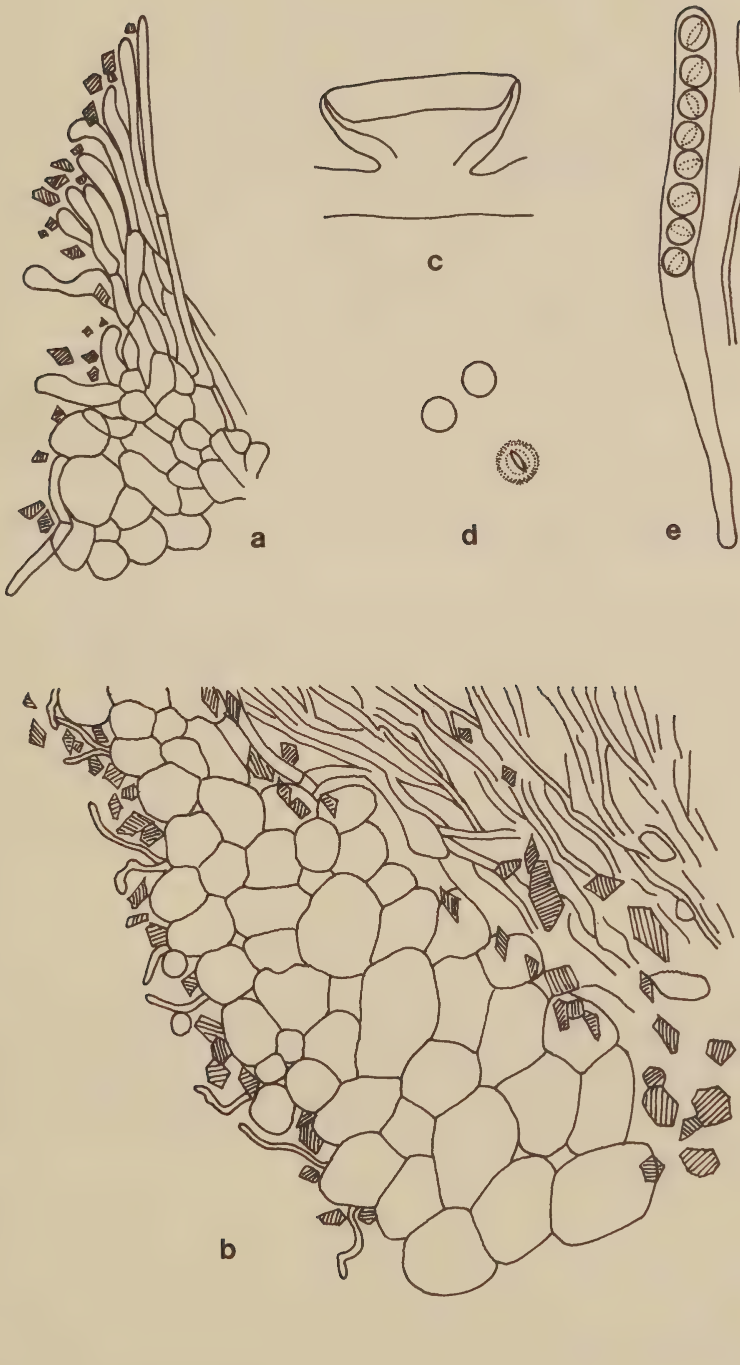
EXSICCATAE EXAMINED: Rehm Ascomyceten #1056, as *Mollisiella myriostylidis*, on stromata of *Phyllachora* sp. on *Myriostylis* sp., Prov. Pichincha, Ecuador, Canzacoto, Lagerheim, VII. 1892, CUP-D 8625 (95-124), FH-General Herb., FH-Patouillard Herb., NY, ZT (isotypes).

OTHER SPECIMENS EXAMINED: **Ecuador**: On *Phyllachora* sp. on leaves of *Myriostylis* sp., Milegalli, Lagerheim, X. 1891, NY; on stromata of *Phyllachora pichinchae* on leaves of *Acalypha* sp., Prov. Pichincha: Mindo, H. Sydow, 4. XI. 1937, W-20337 (Petrak 39154) (paratype of *Parencoelia andina*).

Mexico: [?associated with another fungus causing leaf spot] on leaf of *Persea americana,* intercepted at: San Antonio, Texas, C. Parker, 18. I. 1971, BPI (filed under *Mollisiella* sp.).

Trinidad: On stromata of a species of Phyllachoraceae, Arima, R. Thaxter, 1912-1913, BPI (holotype of *Mollisiella trinitensis*).

FIG. 4. *Parencoelia myriostylidis* (isotype in ZT): **a**. structure of excipulum at margin, **b**. structure of excipulum at flank, **c**. shape of apothecium, from top to bottom showing hymenium, medullary excipulum and ectal excipulum, **d**. two mature ascospores and a young one with a refractive, equatorial plate inside, **e**. ascus and paraphysis apex; **a**, **b**, **d**, **e** x 1000, **c** x 50.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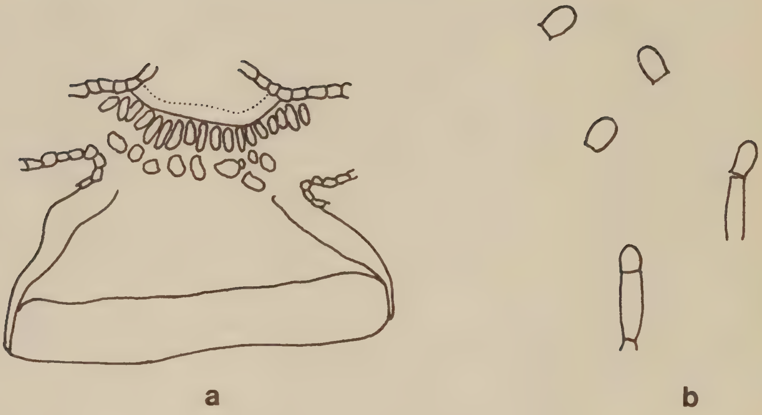

FIG. 5. Anamorph of *Parencoelia myriostylidis* (isotype): **a**. acervulus and apothecium on upper and lower surfaces of a leaf, x 100; **b**. conidia and conidiogenous cells, x 1000.

NOTES: Dennis (1970) distinguished *Mollisiella myriostylidis* in Ecuador from *M. trinitensis* in Trinidad on the basis of apothecial color, size of asci, and size of ascospores given by the original authors. I have examined the type specimens of both species and found that the only difference between them is the color and shape of apothecia. Although *M. trinitensis* has dark brown excipular cells instead of brown cells, and discoid to flat apothecia instead of turbinate to flat ascocarps, they have in common many other features including the size of asci and of ascopores, and are conspecific. I found that some ascospores of the Mexican collection become brownish at maturity.

ACKNOWLEDGEMENTS

I wish to express my deepest appreciation to Prof. Richard P. Korf, Department of Plant Pathology, Cornell University for serving as Chairman of my Special Committee and for kind assistance in all stages of preparation of this paper. I deeply thank the directors and staff members of BPI, FH, NY, W, and ZT for sending specimens on loan; and Mr. Kent E. Loeffler, Department of Plant Pathology, Cornell University for assistance in preparing photographs.

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A NEW SPECIES OF DENCOELIOPSIS AND A SYNOPTIC KEY TO THE GENERA OF THE ENCOELIOIDEAE (LEOTIACEAE)

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A NEW SPECIES OF *DENCOELIOPSIS* KORF

A collection in the Durand Herbarium of Plant Pathology Herbarium of Cornell University (CUP-D 6948) which was misidentified as *Cenangium ravenelii* is not a species of *Unguiculariopsis* but a species of *Dencoeliopsis*. The genus *Dencoeliopsis* was erected by Korf (1971) based on *Peziza johnstonii* Berk., a fungus occurring on the fruit bodies of *Radulum aterrimum* on *Betula* branches (Dennis, 1978). The genus has remained monotypic since then. CUP-D 6948 shares many characteristics with *D. johnstonii* and fits the original generic concept of *Dencoeliopsis* well. But it differs from the type species in lacking of an obvious inner ectal excipulum, possessing a well-developed and pustulate outer ectal excipulum, and having much smaller apothecia, asci and ascospores. It is a distinct species of *Dencoeliopsis*.

From the anatomical point of view, CUP-D 6948 shows a few similarities with the type species of *Encoeliopsis*, *E. rhododendri* (Ces.) Nannf. Cells in outer layers of the ectal excipulum of both fungi are globose, brown, loosely interconnected, and form pustules. However, the species of *Dencoeliopsis* can be distinguished from those of *Encoeliopsis* by the following characters: 1) walls of marginal hyphae thick and granulate to roughened instead of thin and smooth, 2) cell walls of ectal excipulum less carbonized and less pigmented, 3) ascus apices strongly blue in Melzer's reagent, and 4) ascospores fusoid instead of ellipsoid. CUP-D 6948 shows all these features and should be assigned to *Dencoeliopsis*.

CUP-D 6948 is described as a new species of *Dencoeliopsis*:

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[1] Based in part on a Ph. D. thesis presented to the Graduate School, Cornell University. Present address: Department of Mycology, Institute of Microbiology, Academia Sinica, Beijing, People's Republic of China.

Dencoeliopsis betulicola Zhuang, **sp. nov.** (FIG. 1, 2)

Ab D. johnstonii excipuli ectalis strato interiore manifesto absente, receptaculi superficie pustulata, apothecio ascisque ascosporisque parvis, anamorpha praesente differens.

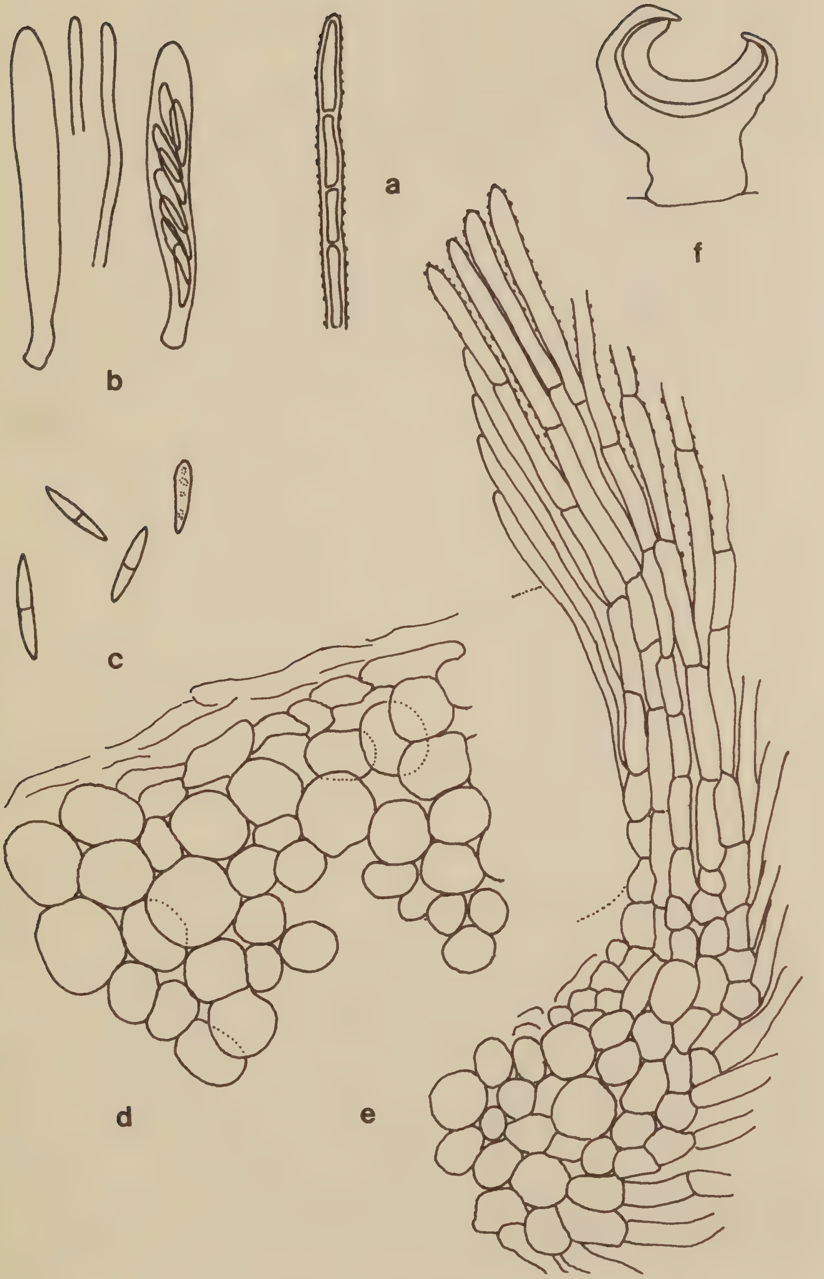
Apothecia cupulate, margin slightly enrolled, 0.4-0.7 mm in diam when dry, short-stipitate, stipe ca. 150 µm long; hymenium pale yellow to beige when dry; receptacle dark brown, surface roughened to furfuraceous. Hairs distributed mostly at margin or on flanks near margin, pale brown, septate, up to 75 µm long, 3.5-4.5 µm wide, arranged parallel at margin and extending beyond the hymenium, walls roughened to granulate, more or less thick. Ectal excipulum of textura globulosa, 30-90 µm thick, thin near margin; cells dark brown, roughened and somewhat thick-walled (0.7-1.0 µm), loosely contacting each other; receptacle pustulate. Medullary excipulum of textura intricata, 10-35 µm thick; hyphae pale brown, subhyaline to hyaline, darker near the ectal excipulum than near the hymenium. Subhymenium indistinguishable. Asci inoperculate, 8-spored, clavate, J+, pore walls strongly blue in Melzer's reagent with or without KOH pretreatment, 41-52 x 5.0-6.1 µm, arising from croziers. Ascospores biseriate, hyaline, fusiform, with small polar guttules and nonseptate when young, nonguttulate and 1-septate at maturity, walls becoming subhyaline to pale yellow in at least some spores outside the ascus, 9.5-12.5 x 1.9-2.4 µm. Paraphyses filiform, simple, 0- to 1-septate, not exceeding asci, 1.5 µm wide.

Anamorph (unnamed): Pycnidia conical, nearly black, 0.9 x 0.4-0.5 mm; structure of pycnidial wall somewhat similar to that of apothecial excipulum, 3-layered; outer layer of textura globulosa, cells dark brown, more or less thick-walled, loosely contacting one other, slightly pustulate; middle layer of textura angularis, cells brown to light brown, thick-walled; inner layer of textura porrecta, cells light brown, giving rise to conidiophores. Conidiophores septate, light brown, producing conidiogenous cells laterally and apically. Conidiogenous cells phialidic, sometimes forming percurrently, subcylindrical, pale brown. Conidia fusoid, pale yellow to light brown, 1-septate, with many small guttules, 13.9-17.6 x 2.3-2.9 µm.

HABITAT: On bark of *Betula* sp.

HOLOTYPE: On bark of *Betula* sp., Chocorua, New Hampshire, USA, W. G. Farlow, received I. 1910, CUP-D 6948; HMAS 45096 (isotype).

FIG. 1. *Dencoeliopsis betulicola* (holotype): **a**. a granulate hair, **b**. paraphysis apices and asci with ascospores, **c**. ascospores, **d**. structure of ectal excipulum at flank, **e**. structure of ectal excipulum at margin, **f**. shape of apothecium, from top to bottom showing hymenium, medullary excipulum and ectal excipulum; **a-e** x 1000, **f** x 50.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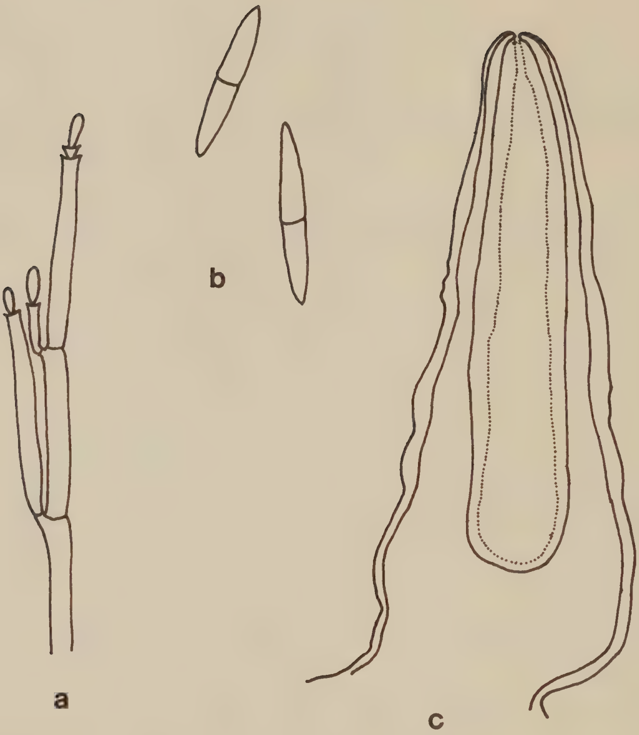

FIG. 2. Anamorph of *Dencoeliopsis betulicola* (holotype): **a**. conidiogenous cells and young conidia, **b**. mature conidia, **c**. shape of pycnidium; **a**, **b** x 1580, **c** x 100.

SYNOPTIC KEY TO THE GENERA OF THE ENCOELIOIDEAE

The subfamily Encoelioideae of the Leotiaceae has been discussed and keys provided by several mycologists (Nannfeldt, 1932; Dennis, 1956, 1978; Kimbrough, 1970; Korf, 1973; Korf & Kohn, 1976; Torkelsen & Eckblad, 1977). The significant characteristics of the species of the Encoelioideae are as follows: apothecia discoid to cupulate, margin often enrolled, receptacle surface powdery, scurfy or furfuraceous due to loosely interconnected ectal cells or short hyphal protrusions; ectal excipulum of textura globulosa to textura angularis, cell walls varying from slightly pigmented to brown; medullary excipulum of textura intricata, tissues sometimes gelatinous; asci subcylindrical to clavate, J+ or J- in iodine reagents; ascospores varying from spherical, broadly ellipsoid, ellipsoid, allantoid, fusoid, or clavate to filiform, hyaline to brown, unicellular to multiseptate; paraphyses cylindrical, filiform (sometimes with apex swollen) or lanceolate, rarely circinate, forming an epithecium in a few genera. They grow as saprophytes or parasites on conifers, angiosperms, fungi or lichens.

A detailed study of the Encoelioideae is beyond the scope of this paper. A synoptic key to the genera of the Encoelioideae appears useful to explore the relationships and distinctions among them. The concept of this subfamily is here accepted in the sense of Korf (1973), with consideration given to the concepts advanced by Nannfeldt (1932) and Dennis (1978). The genera published or assigned to the Encoelioideae in recent years and in this paper are added. The original concepts of the genera are recorded in the key. The construction of the key is similar to that in "Synoptic key to the genera of the Pezizales" (Korf, 1972). Bold face numbers indicate that a genus possessing only a given character state does not possess other character states within the same set. A character state in parentheses shows that all the genera except those indicated by bold face possess that character.

1. Taxon Numbers of Accepted Genera

1. *Ameghiniella* Spegazzini
2. *Cenangiopsis* Rehm
3. *Cenangium* Fries
4. *Chlorencoelia* Dixon
5. *Cordierites* Montagne
6. *Dencoeliopsis* Korf
7. *Discocainia* Reid & Funk
8. *Encoelia* (Fr.) Karsten*
9. *Encoeliopsis* Nannfeldt
10. *Hemiglossum* Patouillard
11. *Holwaya* Saccardo
12. *Ionomidotis* Durand
13. *Nipterella* Starb. ex Dennis
14. *Parencoelia* Petrak
15. *Pestalopezia* Seaver
16. *Phaeofabraea* Rehm
17. *Sageria* Funk
18. *Unguiculariopsis* Rehm
19. *Velutarina* Korf

2. Synoptic Key to the Genera

SUBSTRATE

1-1. Substrate
    a. on fungi or lichens or associated with them 5, 6, 12, **14**, **16**, 18
    b. on conifers **3**, 4, **7**, 13, **17**
    c. on angiosperms **1**, **2**, 4, 5, 6, **8**, **9**, 10, **11**, 12, 13, **15**, 18, **19**
    d. on duff or other substrate 10

ANAMORPH

2-1. Presence of anamorph
    a. acervular 14, **15**, 16
    b. pycnidial 6, 18

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[*] The genus *Banksiamyces* Beaton, which includes a few species of stipitate discomycetes on *Banksia*, is very close to *Encoelia*. Beaton and Weste (1982) have indicated some differences between these two genera. I include this genus under *Encoelia* since I did not examine any specimens of *Banksiamyces* and do not know the exact distinctions between them.

c. hyphomycetous **11, 17**
d. (unknown)

FRUIT BODY CHARACTERS

3-1. Diameter of apothecium
a. less than 1 mm 6, 7, 9, 13, 14, 15, **17**, 18
b. 1-2 mm 1, 3, 5, 6, 7, 8, 9, 13, 14, 15, 16, 18, 19
c. 2-5 mm 1, **2**, 3, 4, 5, 7, 8, 11, 12, 16, 18, 19
d. more than 5 mm 1, 4, 5, 8, **10**, 11, 12

3-2. Shape of apothecium
a. (discoid to cupulate)
b. deeply cupulate 1
c. infundibuliform 4, 5, 18
d. ear-shaped 4, 5, **10**, 12

3-3. Stipe
a. absent **2, 3**, 7, 8, 9, **11**, 12, **13, 14**, 15, **16**, 17, 18, **19**
b. apothecia arising from a common base **1**, 12
c. simple **4, 6**, 8, 9, 15, 17, 18
d. branching **5, 10**

3-4. Color of hymenium
a. whitish to grayish **2**, 6, 9, 13, 18
b. yellowish, orange or ochraceous 6, 10, 18
c. greenish 4, 5, 13, 14, 19
d. brown 3, 4, 6, 8, 9, 10, 13, 14, 15, **17**, 18
e. vinaceous brown 3, 18
f. dark brown, dark purple to nearly black **1**, 5, **7**, 8, **11, 12**, 15, **16**, 19

3-5. Color of receptacle surface
a. whitish to grayish 8, 14, 16, 18
b. yellowish to ochraceous 2, 10
c. greenish 4
d. brown 2, 4, 5, **6**, 8, 10, **13**, 14, **15**, 16, 18, **19**
e. dark brown, dark purple to nearly black **1, 3**, 5, **7**, 8, **9, 11, 12, 17**

3-6. Apothecial margin
a. crenate or irregularly torn 1, 3, 7, 8
b. lobed 12
c. (even)

3-7. Apothecial reaction to KOH
a. ionomidotic **1**, 5, 8, **12**
b. (not ionomidotic)

3-8. Presence of crystals
a. outside apothecium 8, 14
b. inside excipular tissues 14, **16**
c. (not noticed)

3-9. Cells of excipulum
a. vesicular cells present **19**
b. forming pustules on ectal excipulum **1**, 5, 8, **9**, 12, 18
c. a single layer of brown, club-shaped cells 4, **10**

  - d. (not as above)
- 3-10. Presence of an obvious gel matrix in both ectal and medullary excipulum
  - a. present **12**
  - b. (absent)

HAIR CHARACTERS

- 4-1. Presence of distinct hairs or tomentum hyphae
  - a. present on receptacle **4**, 5, 14, **17**, **18**
  - b. only at margin **6**, **9**, 14, 16
  - c. absent **1**, **2**, **3**, 5, **7**, **8**, **10**, **11**, **12**, **13**, **15**, 16, **19**
- 4-2. Shape
  - a. with a swollen base, and a fine, curved apex **18**
  - b. short, rod-shaped, or clavate **4**, **17**
  - c. hyphoid **5**, **6**, **9**, **14**, **16**
- 4-3. Hair wall
  - a. smooth **4**, **5**, 9, **14**, **16**, **17**, 18
  - b. granulate or roughened **6**, 9, 18

ASCUS CHARACTERS

- 5-1. Spore number per ascus
  - a. (8-spored)
  - b. fewer than 8-spored 14, 18
- 5-2. Iodine reaction of pore walls
  - a. blue (J+) **2**, **4**, **6**, 8, **10**, **13**, 14, **15**, **17**, **19**
  - b. none (J-) **1**, **3**, **5**, **7**, 8, **9**, **11**, **12**, 14, **16**, **18**
- 5-3. Shape
  - a. subcylindrical **2**, 3, 4, **5**, 9, 14, **15**, **16**, 18, 19
  - b. clavate **1**, 3, 4, **6**, **7**, **8**, 9, **10**, **11**, **12**, **13**, 14, **17**, 18, 19

PARAPHYSIS CHARACTERS

- 6-1. Shape
  - a. cylindrical or with apex slightly enlarged 1, **4**, **5**, **6**, 7, 8, **10**, 12, **13**, **14**, **16**, **17**, **18**, 19
  - b. with apex obviously swollen **3**, 8, **9**, **11**, **15**, 19
  - c. lanceolate **2**
  - d. with a swollen, lanceolate apex which may become detached 12
  - e. curved to slightly circinate 1, 7, 12
- 6-2. Epithecium formation
  - a. present 9, **11**, **17**
  - b. (absent)

ASCOSPORE CHARACTERS

- 7-1. Shape
  - a. spherical to subspherical 14, 18
  - b. broadly ellipsoid **3**, 14, 18
  - c. ellipsoid to elongated ellipsoid 2, 4, 5, 8, 9, **10**, **13**, 14, **15**, **16**, 17, 18, **19**
  - d. fusoid 6, 9, 17
  - e. allantoid to rod-shaped **1**, 4, 8, **12**
  - f. clavate to filiform 2, **7**, **11**

7-2. Septation
  - a. non-septate **1, 2, 3,** 4, **5, 7, 8, 10, 12, 14, 15, 16, 18, 19**
  - b. 1-3 septate 4, **6, 9, 13**
  - c. transversely multiseptate **11**
  - d. muriform **17**

7-3. Color
  - a. (hyaline)
  - b. faintly or slightly pigmented 1, 5, 6, 12, 14, 15, 19
  - c. brown, with a hyaline band **16**

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ENTOMOPHTHORA SCATOPHAGAE DESC. AMPL. (ZYGOMYCETES: ENTOMOPHTHORALES), A FUNGAL PATHOGEN OF THE YELLOW DUNG FLY, SCATOPHAGA STERCORARIA (DIPTERA: ANTHOMYIIDAE)

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SUMMARY

The yellow dung fly (*Scatophaga stercoraria*) was found on dairy farms in Upstate New York. In late spring some yellow dung flies were infected with the pathogen *Entomophthora scatophagae*, a member of the *E. muscae* species complex that was previously considered a synonym of *E. muscae* by Petch (1934) and MacLeod et al. (1976). A careful comparison of the yellow dung fly pathogen with the characteristics of *E. muscae* showed that it is a distinct species. The conidia of *E. scatophagae* are larger than those of *E. muscae*, contain an average of 15 nuclei, and are not infective to adult *Musca domestica*. The name *E. scatophagae* is resurrected and the original species description by Giard (1888) is amplified. The present report is the first to describe an *Entomophthora* sp. in any detail from wild *S. stercoraria* in the Nearctic.

INTRODUCTION

In 1888 Alfred Giard described a fungus infecting the yellow dung fly, *Scatophaga stercoraria* (Diptera: Anthomyiidae), and named the pathogen *Entomophthora scatophagae* (Zygomycetes: Entomophthoraceae). Giard's description, while brief, is valid (Dr. Richard Korf, personal communication). According to Giard, *E. scatophagae* resembles *E. muscae*, the common pathogen of the house fly, but is differentiated from *E. muscae* by the following characters: larger conidia of a yellowish color, conidia poorly disseminated from host, infected flies die clinging to flowers and shrubs with their legs but not attached by the proboscis as in *E. muscae* infected insects. Because of the similarities in the shape of conidia of both *E. scatophagae* and *E. muscae*, *E. scatophagae* was regarded to be a synonym of *E. muscae* by

Petch (1934) and MacLeod et al. (1976). However, Batko (1964) considered *E. scatophagae* distinct from *E. muscae*, and Keller (1984) also recognized that *E. scatophagae* existed as a separate entity in the *E. muscae* species complex, but stated that members of the species complex required further clarification.

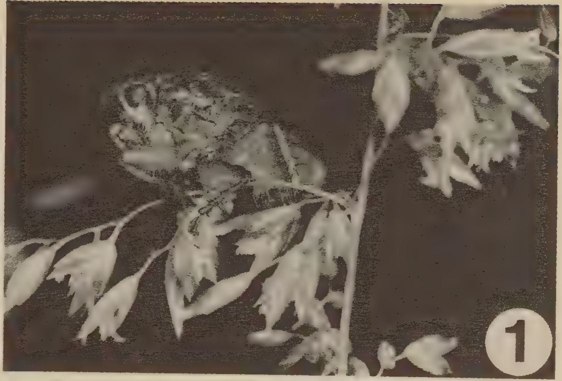
We examined a fungus infecting *S. stercoraria* and compared it to published descriptions and an isolate of *E. muscae* and found substantial differences between these two taxa. This paper clarifies the taxonomic status of *E. scatophagae* and differentiates between the taxa *E. muscae* and *E. scatophagae*. Since no detailed description of *E. scatophagae* has ever been published this study amplifies the description of Giard and resurrects the name *E. scatophagae* that was synonymized by MacLeod et al. (1976) and Petch (1934).

MATERIALS AND METHODS

Field collections of infected *S. stercoraria*

S. stercoraria, the yellow-dung fly, is a predacious fly commonly found on manure in the spring (Fig. 1) (Foster, 1967). Six dairy farms in Cayuga County, New York, were examined at weekly intervals for infected flies. Infected *S. stercoraria* flies were found at one farm on May 21, 1986, but not at the five other dairy farms on the same date, although living *S. stercoraria* were seen on all six farms. On May 21, ten specimens of *S. stercoraria* infected with *E. scatophagae* were collected . All infected flies were found clinging, head downwards, to flowers of orchard grass, *Dactylis glomerata* (Gramineae), with the exception of one specimen that was clinging to a leaf of *D. glomerata*. Infected flies were not found on dandelion, *Taraxacum officinale* (Compositae), mustard, *Brassica rapa* (Cruciferae), or other grass species, although those plants were also present. The cause of this apparent relationship between the infected host and the plant species chosen by the host as a final resting site, is unknown. The legs of infected flies clasped the plant and the mouthparts were extended but not attached to the plant. The

Figs. 1-4: 1. Live adult *Scatophaga stercoraria* feeding on a small sepsid fly. This is the typical position live *S. stercoraria* assume on grasses. 2. Five *S. stercoraria* infected with *E. scatophagae* on flowers of *Dactylis* sp. grass. Note the head downwards position, abdomens with conidiophores emerging through intersegmental membranes, curved tarsi, spread legs, and raised wings. 3. *S. stercoraria* infected with *E. scatophagae*. Note coalescing mass of conidiophores on abdomen, leg extension, wings twisted and raised. 4. Individual of *S. stercoraria* infected with *E. scatophagae*. Note the way the legs clutch the leaf.



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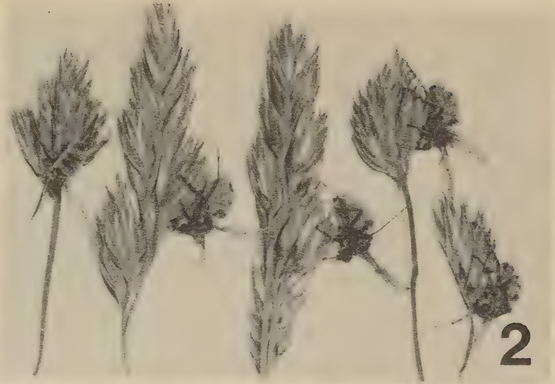

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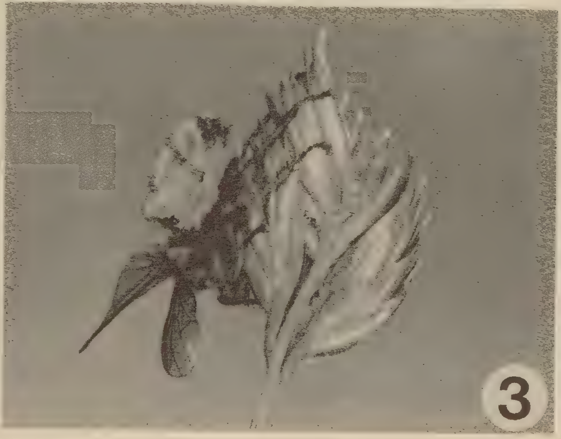

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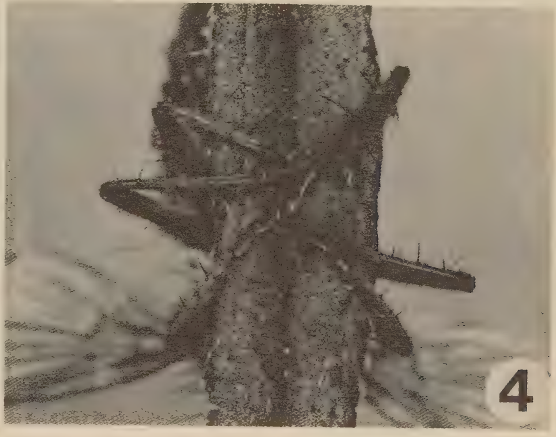

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wings were extended and extensive conidiophore growth was noted on the abdomen of infected flies (Figs. 2, 3, 4). The populations of *S. stercoraria* were large. Infected flies were estimated to constitute approximately 5% of the flies seen.

A week later on May 28, 1986 at a second farm nine infected dead *S. stercoraria* were found clinging to buttercup, *Ranunculus acris* (Ranunculaceae), and thistle, *Cirsium arvense* (Compositae), but not to grasses. All were clinging to the ends of leaves at the tops of the plants. On this date no infected *S. stercoraria* were noted at any of the other farms although living *S. stercoraria* were seen at each farm. No infected *S. stercoraria* were noted after these dates although living flies were still present. This indicates that the occurrence of the mycosis may be limited to certain farms and to a brief period each year.

On both of the above dates living *S. stercoraria* were captured and brought back to the laboratory to be held and observed for infections. Infected dead *S. stercoraria* were collected in the field and brought back to the laboratory for examination. Infected flies were placed on the surface of petri dishes containing 1% water agar. Conidia were collected for examination by inverting a petri dish containing an infected fly over a glass coverslip. Conidia discharged from the conidiophores fell onto the coverslip and adhered there. Either a drop of lactophenol was placed on the coverslip if the conidia were to be measured, or a drop of aceto-orcein stain was used if the nuclei were to be counted. Measurements and nuclear counts were made using bright field microscopy at 400x.

Infection trials were made to test the susceptibility of *M. domestica* to spores of *E. scatophagae*. Six fresh infected *S. stercoraria* cadavers were placed headfirst into water agar dishes (three per dish) over two cages of house flies following the method of Kramer and Steinkraus (1981). The infected flies serving as sources of conidia were removed from the cages seven days after inoculation. A total of 75 healthy adult *M. domestica* were exposed to conidia produced from *S. stercoraria* cadavers. All house flies that died were examined for conidia, hyphal bodies or resting spores for 34 days post-inoculation, however, no mycoses were observed. *M. domestica* exposed to

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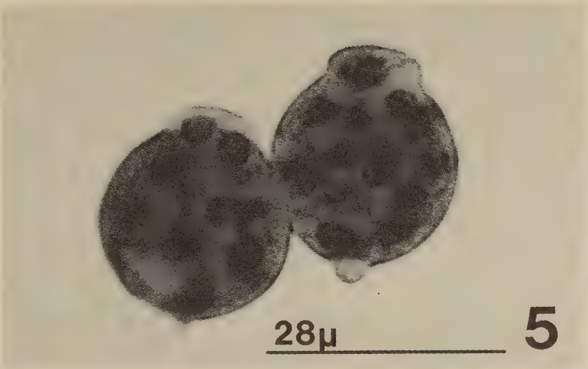
Figs. 5-8. 5. Primary conidia of *E. scatophagae* stained in aceto-orcein to show the nuclei. Note approximately 15 nuclei. Bar equals 28 µm. 6. Primary conidia of *E. scatophagae* stained in aceto-orcein to show nuclei. Note 16-17 nuclei. Bar equals 28 µm, nuclei (n). 7. Primary conidium of *E. scatophagae*. Note the granular nature of the protoplasm surrounding the conidium. Bar equals 30 µm, protoplasm (pr). 8. Secondary conidium forming from a primary of *E. scatophagae*. Note the apical papilla, this feature was not always present. Bar equals 23 µm, secondary conidium (sc).



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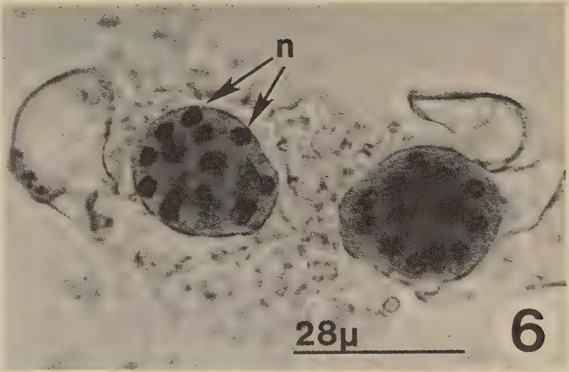

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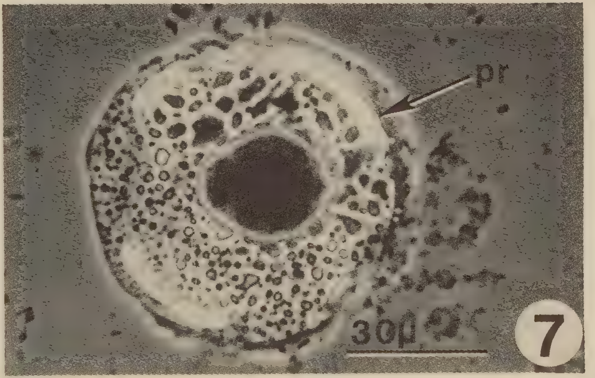

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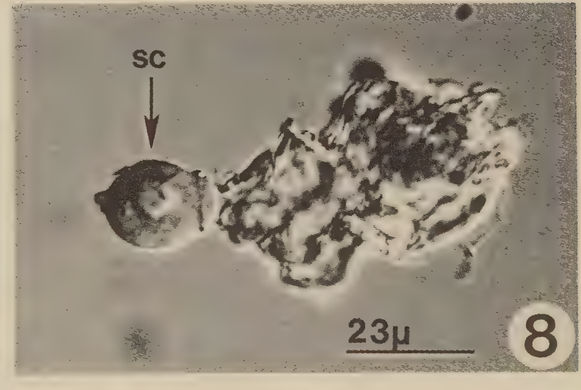

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conidia of *E. muscae* under similar circumstances resulted in virtually 100% mortality in house flies when inoculum from an *in vivo* laboratory culture of *E. muscae* was used (Kramer and Steinkraus, 1981). In the present experiment *E. scatophagae* did not infect *M. domestica*. This strongly suggests that *E. scatophagae* is host specific for *S. stercoraria* and further suggests that *E. muscae* and *E. scatophagae* are separate species in a species complex.

In vitro culture of *E. scatophagae*

Attempts were made to culture the isolate of *E. scatophagae* on egg yolk agar. Four dishes of egg yolk agar, following the recommendation of Müller-Kögler (1959), were prepared. Each dish had a fresh infected field collected *S. stercoraria* affixed with a dab of petroleum jelly to the inner surface of the Petri dish top. The fly cadavers were left overnight to produce conidial showers onto the surface of the egg yolk agar. Unfortunately, all four plates became contaminated and overgrown with bacteria and fungi and were discarded 18 days after inoculation. Therefore, it is not known whether this fungus will grow readily *in vitro*.

RESULTS

Amplified description of *E. scatophagae*

Primary conidia were of the "*E. muscae*-type", i.e., campanulate with a slightly convex base and a pronounced apical papilla (Fig. 5) (MacLeod et al. 1976). They averaged 28.7 µm long by 23.2 µm wide (90 conidia measured from three hosts), length range was 27.5 µm - 31 µm, width range was 21 µm - 24.5 µm. Primary conidia were surrounded by a droplet of protoplasm from the collapsed conidiophore (Fig. 7). Secondary conidia averaged 20 µm long by 17.7 µm wide (Fig. 8) and were produced by direct budding from the primary. Secondary conidia sometimes had an apical papilla but more often did not. The average number of nuclei in primary conidia was 15 with a range of 12 - 19 (n=30) and the nuclei averaged 4 µm in diameter (Fig. 5 and 6). For comparison, the average dimensions of primary conidia of our isolate of *E. muscae* from infected *M. domestica* were 23.5 µm long by 19 µm wide (n=100) and the conidia contained an average of 5 nuclei. This *E. muscae* isolate was initially found infecting *Pollenia rudis* and subsequently used to infect *M. domestica* (Kramer and Steinkraus, 1981). Our isolate of *E. muscae* corresponds to the "group A" proposed by Keller (1984) which he states is probably identical to the *E. muscae* originally described by Cohn (1855). Resting spores were not found in infected *S. stercoraria*.

Voucher specimens of infected *S. stercoraria*: CUP 61893

Host: *Scatophaga stercoraria* L. (Diptera: Anthomyiidae)

Characteristics of infected hosts

Dead infected hosts were found clinging to plants, usually flower heads or leaves of grasses (Figs. 2, 3, 4). Infected flies faced downwards, legs clasping the plant, proboscis extended but not attached by rhizoids, as in *E. muscae* infected insects (Balazy, 1984). Giard (1888) also noted that the proboscis of *S. stercoraria* was not attached in his original description. The wings were extended away from the body and conidiophores grew copiously through the intersegmental membranes of the abdomen. Infected *S. stercoraria* were found only on May 21 and 28, 1986 at two farms in Cayuga County, New York. Infected flies were not seen at any time before or after these dates. Furthermore, the mycosis was not found in epidemic proportions during the present study.

DISCUSSION

From the above evidence, it is clear that *E. scatophagae* is a member of the *E. muscae* species complex. The similarities between these two species in the shape of the primary conidia and the characteristics of infected hosts explain why Petch (1934) and MacLeod et al. (1976), considered *E. scatophagae* to be a synonym of *E. muscae*. Goldstein (1927) believed that the number of nuclei in the conidia was a decisive factor for the separation of genera in the Entomophthoraceae. Keller (1984) used the criteria of nuclear number and nuclear diameter to compare isolates of *E. muscae* from different host species and concluded that *E. muscae* is a species complex. Using these criteria and conidial dimensions Keller divided the *E. muscae* species complex into four groups. Fungal isolates in Keller's "group C", isolated from *S. stercoraria*, had 15-18 nuclei per conidium, the nuclei were 3.4 - 4.2 µm in diameter and the conidia were 25 - 29 µm long by 20 - 23 µm wide, and most likely corresponded with *E. scatophagae*. Keller believed that his results required further clarification. The fungi in Keller's "group C" closely resemble the isolate of *E. scatophagae* we discovered infecting *S. stercoraria*. The isolate of *E. muscae* we used for comparison closely corresponds to the "group A" in the *E. muscae* species complex established by Keller (1984). Keller considered his "group A", which infected *Psila rosae*, *Pollenia rudis*, and *Delia platura*, to be the same species as the *E. muscae* originally described by Cohn (1855).

It is not known how the infected flies found in this study acquired the pathogen. These flies were probably newly emerged adults since they were found in early spring. According to Hammer (1941), *S. stercoraria* probably overwinters in the pupal stage in dung or soil. One possibility is that resting spores are produced in some infected *S. stercoraria*. If so, these resting spores may be deposited in dung and soil and infect newly eclosed adult flies in late May. Carruthers et al. (1985) noted that newly emerged adults of *Delia antiqua* probably acquired infections of *E. muscae* from resting spores present in soil. This may also be the means by which *E. scatophagae* overwinters. However, no resting spores were found in the present study.

While the infections caused by *E. scatophagae* in the present study were not in epidemic proportions, epidemics have been reported. Hammer (1941) found that many adults of *S. stercoraria* died from *Entomophthora* sp. infections between May 23 and July 6, after which it was hard to find any infected flies. Hobby and Elton (1935) noted spectacular epidemics in *S. stercoraria* in April, while Foster (1967) noted thousands of adult yellow dung-flies dying from *E. muscae* at the end of April and in May in California. It seems probable that the epidemics noted by the above authors were caused by *E. scatophagae*. However, insufficient information was given by the above authors to determine if the pathogens they observed were identical to the pathogen in this study.

The present study resurrects the name *Entomophthora scatophagae* from synonomy and amplifies the description of this pathogen given by Giard (1888). *E. scatophagae* was found infecting the yellow dung fly (*S. stercoraria*) in late May in New York State. In order to correctly determine the identity of a pathogen in the *E. muscae* species complex it is necessary to closely examine and describe the isolate, its conidial dimensions, nuclear size and number, and the host and host signs and symptoms. Detailed descriptions of the pathogen will increase the value of studies on pathogens and make it possible for future researchers to compare their work with that of others.

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PUCCINIA STENOTAPHRICOLA, A NEW NAME FOR PUCCINIA STENOTAPHRI CUMMINS AND ITS OCCURRENCE IN AUSTRALIA

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SUMMARY

The name Puccinia stenotaphricola nom. nov. is proposed for the rust of Stenotaphrum secundatum previously known as Puccinia stenotaphri Cummins. Its occurrence in Australia is discussed.

Stenotaphrum secundatum (Walter) Kuntze (Poaceae), buffalo grass, is grown commonly in New South Wales as a lawn grass and is present in most other states of Australia (Jacobs and Pickard, 1981). Overseas, two rusts, Puccinia stenotaphri Cummins and Uromyces setariae-italicae Yosh., have been recorded on species of Stenotaphrum (Cummins, 1971) but until recently there have been no records of a rust on this host genus in Australia.

In March 1986, light rust infection was found on a few plants of buffalo grass in a lawn at Beecroft, a Sydney suburb (Walker and Priest, 1987). The plants were in an area that had not been mown, and long leaves and a few inflorescences had developed. Both uredinia and telia were found; some uredinia were parasitised by Sphaerellopsis filum (Biv. Bern.: Fr.) B. Sutton. During winter 1986, no further rust was seen but it reappeared in the same patch in November 1986. In early December, rust was found on unmown buffalo grass at Glenbrook on the Central Tablelands, about 50 km W of Sydney and in February 1987, heavy rust infection was seen on naturalized buffalo grass growing on the sandy banks of Patonga Creek in the Hunter region, about 40 km N of Sydney. In all cases, the rust has been identified as Puccinia stenotaphri Cummins and these are apparently the first records of it in Australia. A detailed description based on the New South Wales collections follows.

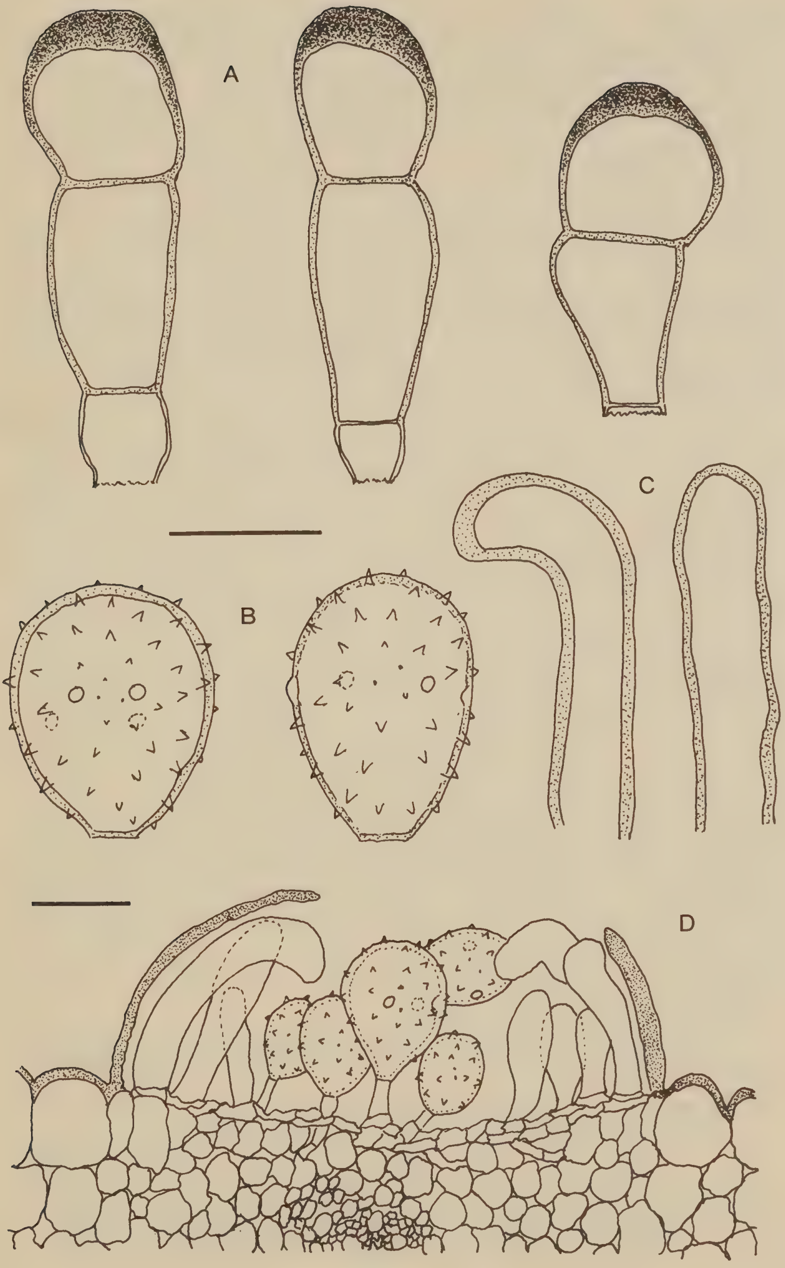
Uredinia (Fig. 1d) mainly epiphyllous, a few hypophyllous, golden brown to pale reddish brown, slightly elongated along the leaf between the veins, 0.25-0.3

(0.5) mm long x 0.1-0.2 mm wide, occurring singly or aggregated into groups 3-4 mm diam., often surrounded by an area of yellowed leaf tissue and infected leaves having a yellow blotched appearance; paraphyses present (Fig. 1c), mainly marginal in the sori, cylindrical to narrowly clavate to undulate in shape, usually incurved towards the apex, 25-50 (55) x 11-13 (15) µm, wall hyaline, variable in thickness, from 1-2 µm at the sides, slightly thicker to 3-4 µm at the apex. Urediniospores (Fig. 1b) yellowish to golden brown singly, obovate to broadly ellipsoidal, 31-37 x 20-26 µm, wall (1) 1.5 µm thick, evenly echinulate with spines 2-2.5 µm apart and up to 1.5 µm high, germ pores 4-5 (6), equatorial to slightly supra-equatorial; basal scar 6-8 µm wide. Telia sparse, dark brown to black, erumpent early to expose the shiny mass of teliospores, generally slightly larger than the uredinia, 0.25-0.5 mm long x 0.1-0.2 mm wide, mainly epiphyllous, a few hypophyllous and these remaining covered longer than telia on the upper leaf surface, aparaphysate, non-locular. Teliospores (Fig. 1a) reddish- brown singly, variable in shape, mainly clavate with wider shorter apical cell and longer narrower basal cell, some spores shorter and wider with cells of equal length, 46-64 x 18-24 µm, wall 1.5-2 µm thick at sides, 5-7 µm thick at apex, smooth, germ pores not observed with certainty but in some spores a lighter coloured area in the thickened apex indicates a possible apical germ pore; pedicel pale brown, short, to 10-12 µm long, usually persistent.

All collections agree well with the descriptions of Puccinia stenotaphri given by Cummins (1945, 1960, 1971) and with a uredinial collection on the same host from Jamaica (DAR 22804). Cummins (1945, 1971) described the urediniospores as 25-28 (30) µm wide but in both the N.S.W. and Jamaica collections no spores wider than 26 µm were seen. Germ pores were mostly 4 or 5 as described by Cummins (1945, 1971) but an occasional spore with 6 pores was observed in local specimens. Pores tended to be slightly supra-equatorial rather than strictly equatorial in a minority of spores in all collections seen.

Overseas, Puccinia stenotaphri is recorded on species of Stenotaphrum and Pennisetum and occurs in India, Portuguese East Africa, Mauritius, Puerto Rico and Florida (U.S.A.) (Cummins, 1971). In New South Wales, two rusts have been recorded on Pennisetum clandestinum Hochst. ex Chiov. (kikuyu grass). These are Phakopsora apoda (Har. & Pat.) Mains which is common in all coastal districts and Puccinia sp. aff. P. substriata Ellis & Barth. var penicillariae (Speg.) Ramachar & Cummins which has been collected in the North Coast district of N.S.W. and in

Fig. 1. Puccinia stenotaphricola (DAR 55670). A. Three teliospores showing variation in size and shape. B. Two urediniospores. C. Two uredinial paraphyses. D. Section of uredinium. Upper bar 20 µm (A-C); lower bar 20 µm (D).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Queensland. Both of these rusts are quite distinct from *P. stenotaphri*. The second rust listed by Cummins (1971) on *Stenotaphrum*, *Uromyces setariae-italicae*, occurs in New South Wales, Queeensland and the Northern Territory and has been recorded on *Brachiaria* spp. in Queensland (Simmonds, 1966) and the Northern Territory (specimens in DAR), on *Eriochloa* spp. in Queensland (Simmonds, 1966), on *Panicum maximum* Jacq. var. *trichoglume* Robyns in New South Wales (DAR 43426) and Queensland (Alcorn, 1976) and on *Setaria glauca* (L.) Beauv. in New South Wales (specimens in DAR) and Queensland (Simmonds, 1966). Cummins (1971) lists eleven grass genera as hosts for this rust. All these rusts are quite distinct from *P. stenotaphri*. *Uromyces setariae-italicae* differs in its aparaphysate uredinia and unicellular teliospores, *Puccinia substriata* var. *penicillariae* in its aparaphysate uredinia and *Phakopsora apoda* in morphology of uredinia, telia and teliospores.

An unfortunate nomenclatural problem surrounds the use of the name *Puccinia stenotaphri* Cummins. Originally, Cummins (1945) made the new combination *Puccinia stenotaphri* (H. Sydow & Sydow) Cummins based on *Uredo stenotaphri* H. Sydow & Sydow (1909) described on *Stenotaphrum glabrum* Trin. from Portuguese East Africa. The Sydows described only uredinia and made no mention of paraphyses. Cummins (1945) did not examine the Sydow collection, noted that the Sydows did not describe paraphyses, and gave a full description in English of paraphysate uredinia and telia based on a different collection (from Mauritius). As no Latin description was provided (being obligatory for a new species after 1 Jan 1935, Art. 36, International Code of Botanical Nomenclature 1983), Cummins' (1945) description and new combination cannot be regarded as valid publication of a new species of *Puccinia* (even though he described telia). However, the name *Puccinia stenotaphri* (H. Sydow & Sydow) Cummins must be considered a validly published and legitimate new combination based on the Sydow uredinial collection. Cummins' (1960) later name *Puccinia stenotaphri* Cummins with a Latin description and teleomorphic type is an illegitimate later homonym of the binomial *P. stenotaphri* (H. Sydow & Sydow) Cummins, typified by an anamorph (Art. 59, International Code of Botanical Nomenclature 1983).

A new name is thus required for *Puccinia stenotaphri* Cummins (1960) and the following synoymy is proposed:

Puccinia stenotaphricola J. Walker nom. nov.
Syn. *P. stenotaphri* Cummins, *Bull. Torrey. Bot. Club* 87 : 40, 1960, based on telia (a later homonym of *P. stenotaphri* (H. Sydow & Sydow) Cummins, *Bull. Torrey Bot. Club* 72 : 213, 1945 based on uredinia, basionym *Uredo stenotaphri* H. Sydow & Sydow, *Ann. Myc.* 7 : 544, 1909).

The exact identity of Uredo stenotaphri H. Sydow & Sydow must await study of the type specimen. Even if it is found to be identical with P. stenotaphricola, it plays no part in the nomenclature of this teleomorphic species, being based on uredinia and there having been no mention of any teleomorph in the original description (Art. 59.2, International Code of Botanical Nomenclature, 1983).

It is possible that the rust of buffalo grass is more widely distributed in Australia than the present limited findings in the Central Coast and Central Tablelands districts of N.S.W. would suggest. Infection on naturalized unmown buffalo grass at Patonga (DAR 58980) was heavy and the rust appeared to have been established there for some months at least. The original detection in the home garden at Beecroft probably represented spread from some other source. Rust has not been seen in buffalo grass lawns inspected in various Sydney suburbs and the limited collections made so far have all been on long, unmown grass. No explanation can be given for the occurrence of this rust in New South Wales and how, when and where it entered Australia is not known.

Specimens examined : all on Stenotaphrum secundatum : in garden, Beecroft, N.S.W., Australia, 27.iii.1986, R.D. Pares, DAR 55664, II, III, first record in Australia (Walker and Priest, 1987); same loc., 2.iv.1986, R.D. Pares, DAR 55670, II, III; same loc. 17.xi.1986, R.D. Pares, DAR 57109, II; near waterhole, Glenbrook, N.S.W., 7.xii.1986, P. Wong, DAR 58009, II, III; along Patonga Creek, Patonga, N.S.W., 4.ii.1987, J. Walker, DAR 58980, II, III; Montpelier, Portland, Jamaica, 6.iv .1961, R.I. Leather, DAR 22804 (ex IMI 87795), II.

The author is grateful to Dr. R.D. Pares for bringing this rust to his notice and making observations in his Beecroft garden; to Dr. J.L. Alcorn (Herb. BRIP) and to Mr. I. Pascoe (Herb. VPRI) for information on rust records in Queensland and Victoria, and to Professor G.B. Cummins (Herb. ARIZ) and Dr. B.C. Sutton (Herb. IMI) for reading and commenting on the paper during its preparation.

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MYCOTAXON

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REDISPOSALS AND REDESCRIPTIONS IN THE MONOCHAETIA - SEIRIDIUM, PESTALOTIA - PESTALOTIOPSIS COMPLEXES. VIII. ON THE STATUS OF *MONOCHAETIA CAMELLIAE, M. OSYRIDELLA* AND *PESTALOTIA GAURAE*.

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Monochaetia camelliae and *Pestalotia gaurae* are reduced to synonymy with *Pestalotiopsis karstenii* and *Pestalotiopsis uvicola* respectively. *Monochaetia osyrella* is redescribed.

12. *Monochaetia camelliae* Miles
Mycologia 18: 167, 1926.

On leaves of *Camellia japonica*, Columbus, Mississippi, U.S.A., 17.III.1922, S.H.Livingston # 460 [type in BPI; co-type in NY sterile].

The packet in BPI contains a single piece of leaf bearing two leaf spots. The fungus described by Miles (1926) is present on the smaller ash gray leaf spot at the distal end of the leaf. The revised description of the fungus given below and the illustrations in Figs. 1-7, compare well with earlier accounts of *Pestalotiopsis karstenii* (Saccardo & Sydow) Steyaert (Steyaert 1949; Sutton 1961), based on the material on leaves of *Camellia* sp. distributed by Desmazières in 1840 as Crypt. Pl. de France exsic. # 1084 under the name *Pestalotia guepini*. Steyaert (1949) recognised the heterogeneous nature of this exsiccatum which, compounded by the inadequate specific description, resulted in considerable confusion in delimitation of species occurring on *Camellia* spp. After examining the exsiccatum in PC and BR, he described three species of *Pestalotiopsis: P. guepini, P. karstenii* and *P. gallica* and designated the material in PC as the neotype of *P. guepini*. Sutton's account of the fungus was based on the exsiccatum in BM, BR, K, PC and other collections in IMI from Italy and England. Later, Sutton (1969) redisposed *P. karstenii* as *Monochaetia karstenii*. He (1975) also considered *Coryneum camelliae* Massee apud Cooke a possible synonym of *Pestalotiopsis guepinii* (Desmazières) Steyaert [= *P. maculans* (Corda) Nag Raj (Nag Raj 1985)]. The morphology of the conidia, implied in his account of *C. camelliae*, suggests that the fungus is more likely to be *P. karstenii*. The conidia of *P. maculans* are longer and wider, and have longer median cells. While the three median cells of *P. karstenii* are concolorous, those of *P. maculans* are versicolorous, with the central cell most darkly pigmented. *P. karstenii* is redescribed below and illustrated in Figs. 1-7.

Pestalotiopsis karstenii (Saccardo & Sydow) Steyaert, Bull. Jard. Bot. Brux. 19: 305, 1949.
≡ *Pestalotia inquinans* Karsten, Hedwigia 30: 301, 1897 [later homonym of *Pestalotia inquinans* Cooke & Harkness, 1884].
≡ *Pestalotia karstenii* Saccardo & Sydow in Saccardo, Syll. Fung. 14: 1030, 1899 [*nom. nov.*].
≡ *Monochaetia karstenii* (Saccardo & Sydow) Sutton, Can. J. Bot. 47: 2091, 1969.
= *Monochaetia camelliae* Miles, Mycologia 18: 167, 1926.
= *Coryneum camelliae* Massee apud Cooke, Grevillea 20: 8, 1891; fide Sutton, Mycol. Pap. 138: 70, 1975.

Foliicolous. Conidiomata stromatic, acervuloid to pycnidioid, epiphyllous, scattered to gregarious, occasionally confluent, orbicular to oval in outline with a central punctiform opening, broadly conical in sectional view, 210-350 μm wide, 90-150 μm deep, unilocular, glabrous, brown; basal stroma and lateral walls 10-15 μm thick, of 'textura angularis', cells in outer layers thick-walled, brown to dark brown and encrusted, cells in the inner layers thin-walled, pale and smooth. Conidiophores lining the cavity of the conidioma, septate, irregularly branched, up to 30 μm long, invested in mucus. *Conidiogenous cells* phialidic, ampulliform, lageniform or subcylindrical, hyaline, smooth, 7-14 X (2-)2.5-3 [x̄ = 10 X 2.7] μm, with up to 3 percurrent proliferations. *Conidia* blastic-annellidic, fusiform, 4-septate, occasionally 5-septate, septa and periclinal walls darker, 16-23 X (4.5-)5-6 [x̄ = 19 X 5.5] μm, bearing appendages; basal cell obconical with an obtuse base, hyaline, smooth-walled, subhyaline near the end septμm but hyaline for the most part, 2-4(-4.5) [x̄ = 3] μm long; median cells 3 (or 4), subcylindrical to doliiform, pale brown and mostly concolorous, but occasionally the upper two cells slightly darker than the second cell from the base, wall thick, smooth and slightly collapsed between the septa, together 11-14.5 [x̄ = 12.5] μm long (second cell from the base 4-5(-5.5) [x̄ = 4.5] μm; third and fourth cells 3-4.5 [x̄ = 3.7] μm); apical cell obconic, somewhat swollen, hyaline, thin-walled, smooth, 3-4 [x̄ = 3.5] μm long; appendage tubular, coarse, flexuous, single and unbranched or branched with 2-3 branchlets; appendage or branchlets 3-16(-22) [x̄ = 9.5] μm long; basal appendage absent; mean conidium length/width ratio = 3.45:1.

Habitat: On leaves of *Camellia japonica*.

Specimen examined: BPI, Columbus, Mississippi, U.S.A., 17.III.1922, S.H.Livingston # 460 [type of *Monochaetia camelliae* Miles].

Known distribution: England, France, Italy, U.S.A.

Teleomorph: Unknown.

Sutton (1980) has recorded a wider host range [*Allium sativum*, *Camellia caudata*, *Camellia* sp., *Cassia obtusifolia*, *Curcuma decipiens*, *Daucus carota*, *Peltophorum ferrugineum*, *Rhododendron* sp., and from bird feathers] and wider geographical distribution to include Czechoslovakia, Dominica, India and North Borneo. I have not been able to verify these records.

13. *Monochaetia osyrella* Saccardo & D.Saccardo
Syll. Fung. 18: 486, 1906.

On dead twigs of *Osyris alba*, S.Colomba, Italy, IX.1903.

Two coelomycetes were described as occurring on *Osyris alba*: *Pestalotia osyridella* Tassi (1904) and *Monochaetia osyridella*

Bubák (1906). Saccardo & D. Saccardo (1906) redisposed *Pestalotia osyridella* Tassi in *Monochaetia* and gave the species a new epithet.

Type collections of both species have been examined. The type specimen of *P. osyridella* Tassi is the basis for the Saccardos' binomial. This specimen comprises several twigs of the host, only one of which bears sparse conidiomata of the coelomycete. The type collection of *M. osyridella* Bubák contains better material on a few pieces of twigs. I consider that both belong in a single species of *Monochaetia*. The fungus, with the correct nomenclator, is redescribed below and illustrated in Figs. 8-22.

Monochaetia osyrella Saccardo & D. Saccardo, Syll. Fung. 18: 486, 1906.
≡ *Pestalotia osyridella* Tassi, Boll. Lab. Ort. Bot. R. Univ. Siena 6: 127, 1904.
= *Monochaetia osyridella* Bubák, Bull. Herb. Boiss. (ser. II) 6: 484-485, 1906.

Caulicolous. Conidiomata stromatic, acervuloid, scattered to gregarious, semi-immersed, intraperidermal in origin, orbicular to oval or irregular in outline, applanate to broadly conical in sectional view, 200-450 μm wide, 70-110 μm deep, unilocular, locule often irregularly and incompletely divided, glabrous, dark brown to black, dehiscing by an irregular break in the overlying host tissue; basal stroma up to 10 μm thick, of pale brown to hyaline, thin-walled 'textura angularis', lateral walls of similar tissue, but dark brown to black with thick-walled cells. Conidiophores arising from the upper cells of the basal stroma, septate, irregularly branched and up to 40 μm long, occasionally reduced to conidiogenous cells, hyaline, smooth-walled, invested in mucus. Conidiogenous cells phialidic, cylindrical to lageniform, hyaline, smooth-walled, 12-24 X 2-3(-3.5) [$\bar{x}$ = 16.5 X 2.5] μm, with up to 5 percurrent proliferations. Conidia blastic-phialidic, fusiform, straight or curved, 4-euseptate, 20-29 X 5.5-7.5 [$\bar{x}$ = 24.5 X 6.5] μm, bearing appendages; basal cell obconic with a narrow truncate base, hyaline, with thin and smooth walls, 3-5.5 [$\bar{x}$ = 4.2] μm long; median cells 3, doliiform, unequal with the central cell being the smallest, together 13-21.5 [$\bar{x}$ = 17] μm long (second cell from the base 5-8 [$\bar{x}$ = 6.5] μm; central cell (3-)3.5-5.5 [$\bar{x}$ = 4.5] μm; fourth cell 4-8 [$\bar{x}$ = 6] μm), brown, periclinal wall thick, dark, verruculose and with or without constrictions at the septa, end septa as thick and dark as the periclinal wall, 2 median septa very thin; apical cell conical, hyaline, with thin and smooth walls, (2-)3-4 [$\bar{x}$ = 3.5] μm long; appendages tubular, attenuated, unbranched, flexuous; apical appendage single, 10-20 [$\bar{x}$ = 15] μm long; basal appendage often lacking, but when present, centric and occasionally obliquely oriented, up to 7 μm long; mean conidium length/width ratio = 3.8:1.

Habitat: On twigs of *Osyris alba*.

Specimens examined: 1. SIENA [Holotype], S.Colomba, Siena, Italy, IX.1903; 2. BPI, Ulcinj, Yugoslavia, 18.IV.1903, F.Bubák [type of *Monochaetia osyridella* Bubák, issued as exsiccati labelled Fungi Montenegrini].

Known distribution: Italy, Yugoslavia.

Teleomorph: Unknown.

14. *Pestalotia gaurae* Guba
Monograph of *Monochaetia* and *Pestalotia*: 145, 1961.

On *Gaura parviflora*, Hays, Kansas, U.S.A., 10.VII.1930, E. Bartholomew, # 11040 [Holotype in FH as *Pestalotia oenotherae*].

The type specimen has been examined. *Pestalotia gaurae* is congeneric with *Pestalotiopsis maculans* (Corda) Nag Raj. Its general morphological features overlap those of *P. uvicola* (Spegazzini) Bissett (Nag Raj 1986) with minor quantitative differences. *P. uvicola* conidiomata possess a thick, hyaline, lenticular tissue in the area of dehiscence; conidiogenous cells are narrower; basal cells of the conidia are longer; the two upper of the three median cells are unequal; the apical cell is shorter; the apical appendages are shorter and form a closely aggregated crest; the basal appendage is often absent, but when present is very short. I prefer to broaden the species concept of *P. uvicola* to cover these differences and treat *Pestalotia gaurae* as its synonym. It is described below and illustrated in Fig. 23.

Pestalotiopsis uvicola (Spegazzini) Bissett
Can. J. Bot. 60: 2572, 1982.
≡ *Pestalotia uvicola* Spegazzini, Riv. Viticoltura Enologia Ital. 2: 340, 1878.
= *Pestalotia gaurae* Guba, Monograph of *Monochaetia* and *Pestalotia*: 145, 1961.

Caulicolous. *Conidiomata* stromatic, pycnidioid, scattered to gregarious and often confluent, intra-peridermal to subperidermal in origin, orbicular to oval or angular in outline, crateriform in surface view, broadly conical in sectional view, 200-500 μm wide, 130-200 μm deep, unilocular, glabrous, black; lateral wall and basal tissue up to 20 μm thick, of 'textura angularis', cells hyaline, becoming pale brown in the zone bordering the area of dehiscence. *Conidiophores* lining the cavity of the conidioma, short, sparsely branched and septate or reduced to conidiogenous cells, hyaline, invested in mucus. *Conidiogenous cells* phialidic, ampulliform or lageniform to subcylindrical, hyaline, smooth, 5-11(-13) X 2-3 [$\bar{x}$ = 7.5 X 2.5] μm with up to 3 percurrent proliferations. *Conidia* blastic-phialidic, fusiform to ellipsoid, 4-septate, 19-21 X 6-7 [$\bar{x}$ = 20 X 6.5] μm, bearing appendages; basal cell obconic with a truncate base, hyaline below, subhyaline above, smooth-walled, 3-3.5 [$\bar{x}$ = 3.2] μm long; 3 median cells short cylindrical to doliiform, pale brown and concolorous, septa darker than the periclinal wall, wall rugose and minutely verruculose with slight or marked constrictions at the septa, together 12-14 [$\bar{x}$ = 13] μm long (first cell from base 5-6 [$\bar{x}$ = 5.5] μm; central and third cell from base 3.5-4 [$\bar{x}$ = 3.7] μm); apical cell conical with a somewhat blunt apex, hyaline, 3-4 [$\bar{x}$ = 3.5] μm long; appendages tubular, unbranched, attenuated, flexuous; apical appendages 2-5, with independent loci of origin at the apex of the apical cell, occasionally with one or two inserted in a submedian position, 7-16 [$\bar{x}$ = 11.5] μm long; basal appendage usually present, single, attenuated, centric, 3-5 [$\bar{x}$ = 4] μm long; mean conidium length/width ratio = 3:1.

Habitat: On *Gaura parviflora, Vitis vinifera*.

Specimens examined: 1. LPS 11865 [Holotype of *P. uvicola*], Conegliano, Italy, C. Spegazzini; 2. FH (as *Pestalotia oenotherae*), Hays, Kansas, U.S.A., 10.VII.1930, E. Bartholomew, # 11040 [Holotype of *Pestalotia gaurae*].

Known distribution: Italy, U.S.A.

Teleomorph: Unknown.

Acknowledgments

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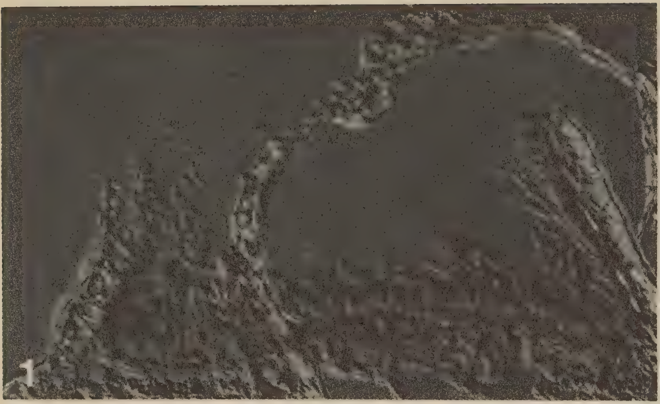
Legends to illustrations:

Figs. 1-7. *Pestalotiopsis karstenii* ex type of *Monochaetia camelliae* in BPI. Fig. 1. v.s. of a conidioma, ca X 190; Figs. 2-5. Conidiophores with developing conidia, X 1000, arrows in figs 2-4 mark percurrently proliferating conidiogenous cells; Figs. 6 & 7. Mature conidia, note variation in conidium septation and appendage morphology.

Figs. 8-14. *Monochaetia osyrella* ex type of *Pestalotia osyridella* in SIENA. Figs. 8-10. Conidiogenous cells with developing conidia, X 1250; Figs. 11-14. Mature conidia, X 1000, note the verruculose walls on the median cells of the conidia.

Figs. 15-22. *Monochaetia osyrella* ex type of *Monochaetia osyridella* in BPI. Fig. 15. v.s. of conidioma, ca X 480; Figs. 16-18. Conidiophores with developing conidia, X 1250, arrows in figs. 16 & 17 indicate percurrent proliferations; Figs. 19-22. Mature conidia, X 1000, note the verruculose walls in fig. 19.

Fig. 23. *Pestalotiopsis uvicola* ex type of *Pestalotia gaurae* in FH. A. v.s. of conidioma; B. Conidiophores and conidiogenous cells with developing conidia.; C. Mature conidia.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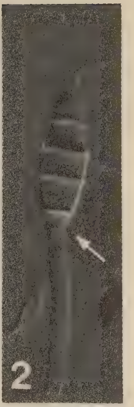
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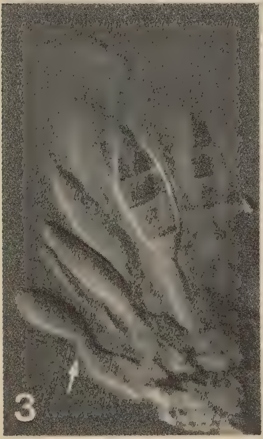
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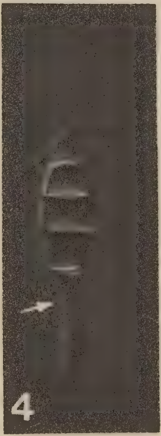
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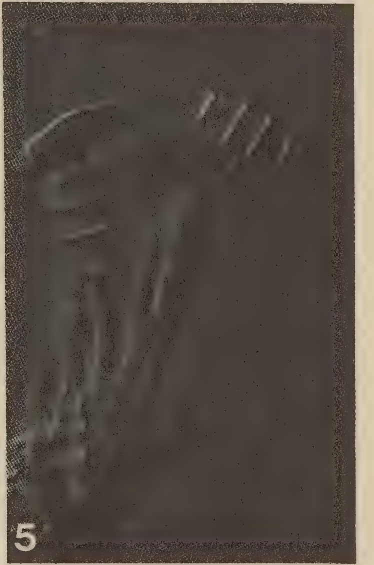
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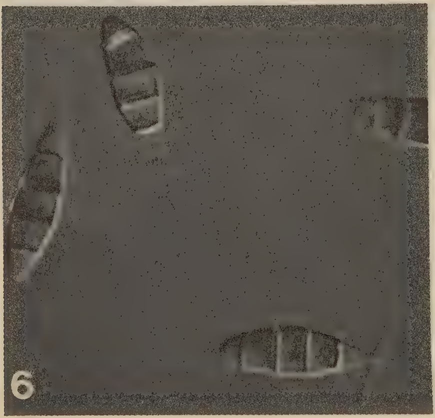
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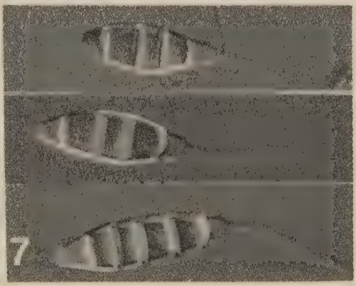
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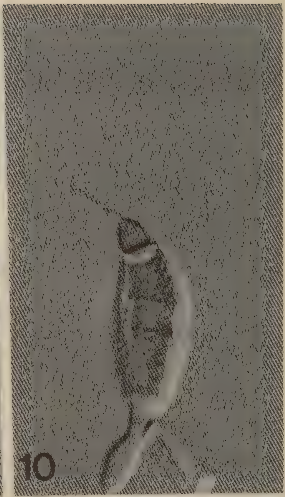
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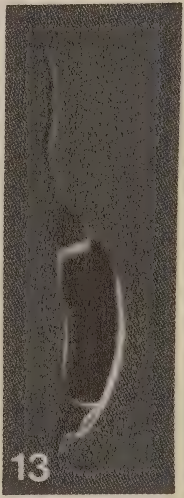
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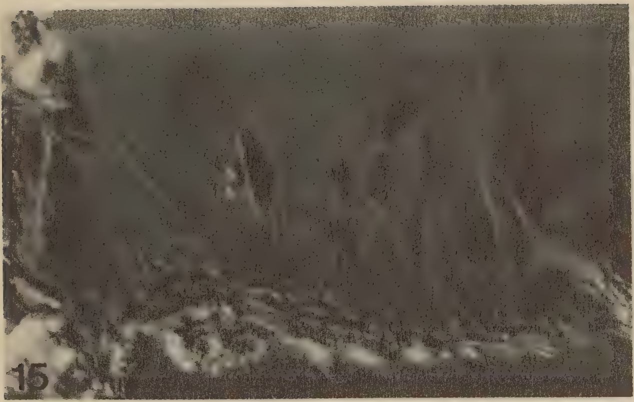
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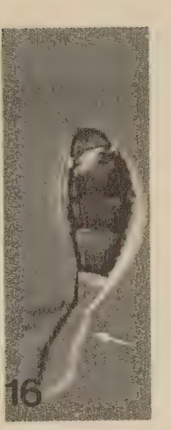
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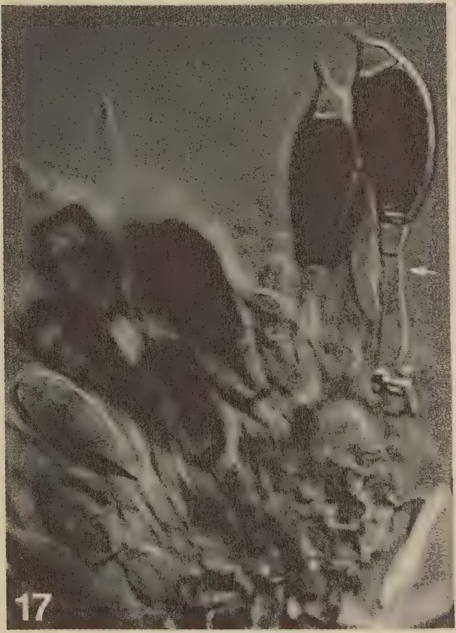
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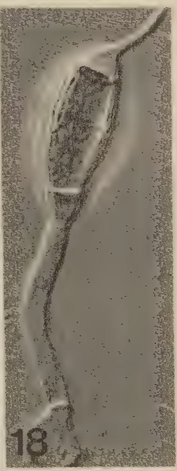
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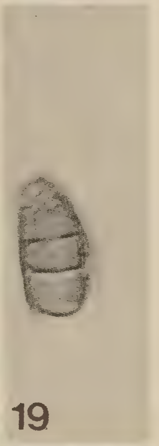
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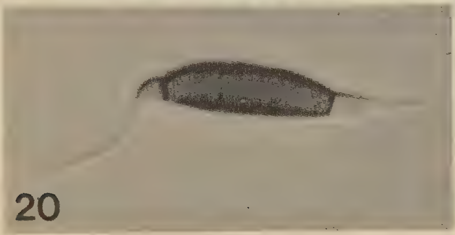
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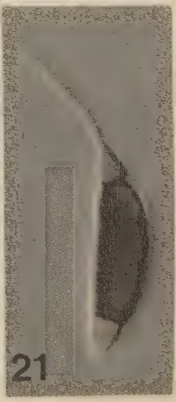
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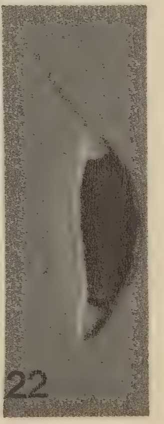
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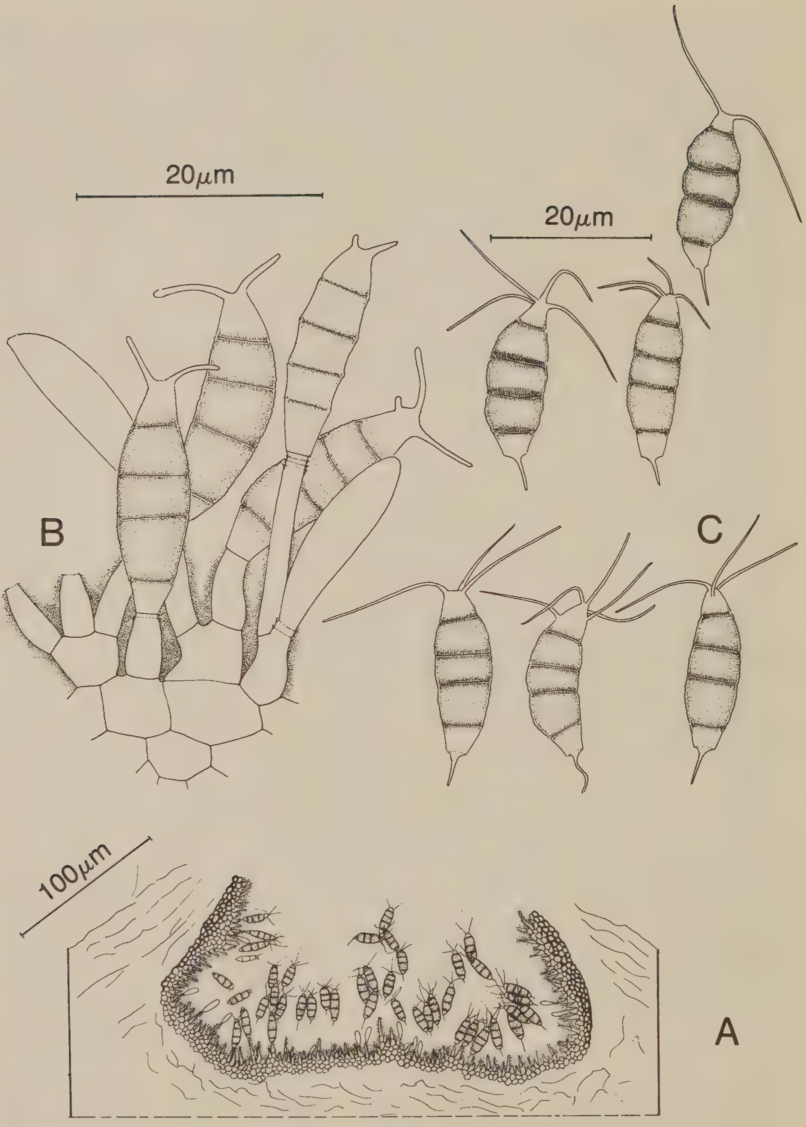
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MYCOTAXON

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STUDIES IN THE GENUS PHOMA. XI. CONCERNING PHOMA LYCOPERSICI, THE ANAMORPH OF DIDYMELLA LYCOPERSICI, CAUSAL ORGANISM OF STEM CANKER AND FRUIT ROT OF TOMATO.

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ABSTRACT

Phoma lycopersici Cooke, the anamorph of *Didymella lycopersici* Klebahn, causal organism of stem canker and fruit rot of tomato, is described and illustrated. Colony characteristics on agar media and pycnidial anatomy are documented. It is compared with other *Phoma* species known to occur on the same host, particularly *P. destructiva* Plowr. and *P. exigua* Desm.

INTRODUCTION

A number of taxa classified in the genus *Phoma* Sacc. have been recorded from members of the Solanaceae, especially *Lycopersicon esculentum* Mill. [tomato] and *Solanum tuberosum* L. [potato]. These fungi exhibit various degrees of specialization in terms of host specificity and capacity to induce disease. Some, such as *Phoma glomerata* (Corda) Wollenw. & Hochapf. [described from tomato fruit rot as *Phoma alternariaceum* F.T. Brooks & Searle (1921)], which has been previously treated in this series of papers (White and Morgan-Jones, 1987), and *P. exigua* [isolated from stem and fruit rots of tomato in New Zealand (Laundon, 1971)] are plurivorous and have a wide host range extending to other phanerogamic plant families. The latter is known to induce gangrene of potato (Boerema, 1967). Others, such as *P. destructiva* and *P. lycopersici*, are restricted within the Solanaceae to one or, at most, a few hosts. *Phoma lycopersici* appears to be confined to tomato, although there are conflicting reports in this regard. *Phoma destructiva* has been reported to cause fruit rot of pepper [*Capsicum frutescens* L. (*C. annuum* L.)] as well as tomato. Jamieson (1915) showed *P. destructiva* to cause a leaf spot of eggplant [*Solanum melongena* L.] and potato in inoculation experiments, but tubers of the latter were unaffected. No infection could be induced in pepper plants. Dennis (1948), while noting the observation made by Jamieson concerning the incapacity of *P. destructiva* to attack potato tubers, stated that *P. lycopersici* does so readily.

It is not always possible, in retrospect, to determine the extent of occurrence of particular species since identity determinations on which records are based are not always fully reliable and there is frequently, in the absence of voucher specimens, no means of verification readily available. As has been alluded to in previous papers in this series, ill-defined species concepts,

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nomenclatural confusion, and taxonomic misinterpretation are commonplace in the literature dealing with *Phoma*. Not only does a plethora of names exist for individual fungi, sometimes involving more than one genus, but the distinctions between many of them are not fully understood or satisfactorily documented. The situation for species occurring on solanaceous hosts is no exception. On potato alone, for example, the following are among the supposed species recorded; *P. eupyrena* Sacc., *P. exigua* Desm., *P. foveata* Foister, *P. multirostrata* (Mathur, Menon & Thirum.) Dorenbosch & Boerema, *P. nebulosa* (Pers.) Berk., *P. solani* Cooke & Harkn., *P. solanicola* Prill & Del., *P. solaniphila* Oud., and *P. tuberosa* Melhus, Rosenb. & Schultz. In addition, there exist such binomials as *Ascochyta solani-tuberosi* Naumov. The latter, together with *Phoma solanicola*, *P. solaniphila* and *P. tuberosa*, are now accepted as synonyms of *P. exigua* var. *exigua* (Boerema and Dorenbosch, 1973). *Phoma foveata* which, for some years, was classified as a pigment-producing variety of that species [*P. exigua* var. *foveata* (Foister) Boerema] (Boerema, 1967) is now recognized as a separate entity (Boerema *et al*., 1987). Illustrative of the nomenclatural complexity and confusion extant in this group of fungi is the fact that over sixty binomials in eight different genera have been applied to what is now known as *Phoma exigua* var. *exigua*. Inadequacy of descriptions compounds the problem of determining which species individual authors actually had under study in particular instances.

Aulakh *et al*. (1969) presented an account of cultural variability and host range of *Phoma destructiva* in India. However, as Boerema and Dorenbosch (1973) have pointed out, that study probably included more than one entity. Similarly, in the study of some *Phoma* species reported by Grimes *et al*. (1932), which included a description of *Phoma destructiva* isolated from butter, there must remain some uncertainty about proper application of binomials. In a key to seven *Phoma* species, *P. destructiva* was noted as being parasitic on tomato plants and ivy [*Hedera helix* L.]. Isolates from tomato, determined by Aulakh *et al*. (1969) to represent *P. destructiva*, were grouped into three culturally distinct varieties that were said to be, to quote, "distinct biological forms". Varying results were obtained when one of these was artificially inoculated onto eight different solanaceous hosts, but young fruits of *Capsicum frutescens*, *Datura alba* Nees [*D. fastuosa* L.], *Solanum melongena* and *Withania somnifera* Dun. were found to be susceptible to infection. In their experiments, neither leaves nor tubers of potato became infected.

Over the years, a number of authors have discussed the resemblance between *P. destructiva* and *P. lycopersici* (Brooks and Searle, 1921; Dennis, 1946; Knight, 1960; Laundon, 1971; Boerema and Dorenbosch, 1973; Sutton, 1980). It has generally been accepted that the two species are morphologically closely similar in most respects and can only be distinguished by cultural characteristics. As can be expected, published accounts of these taxa vary in thoroughness and not all authors are in agreement over particular details, including colony appearance *in vitro*. Allowing for the fact that both species are somewhat variable, they can, nevertheless, be readily distinguished.

To facilitate better understanding of some of the species of *Phoma* associated with members of the Solanaceae, a study of *P. eupyrena* (Morgan-Jones and Burch, 1988), *P. exigua*, *P. destructiva* and *P. lycopersici* has been undertaken. Our observations on the latter are reported herein. Treatments of *P. destructiva* and *P. exigua* will be published in forthcoming papers in this series.

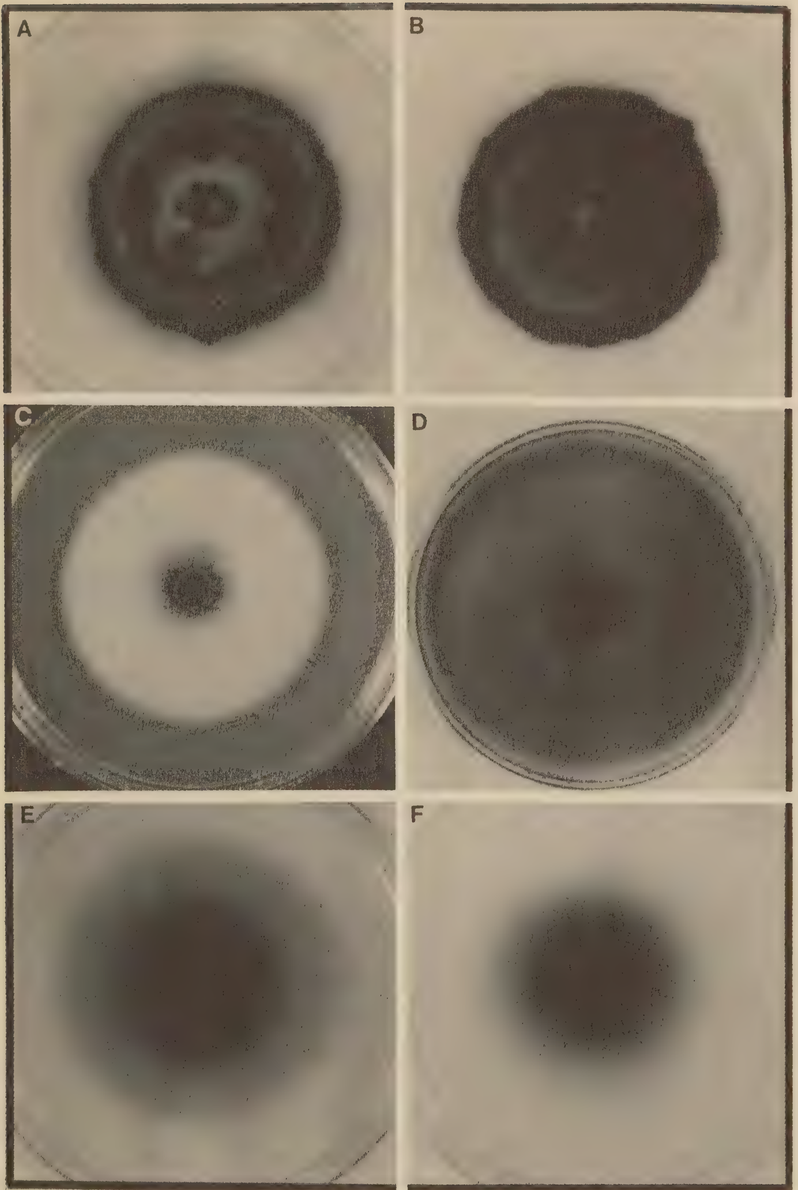


PLATE 1. *Phoma lycopersici*. A, 14-day-old colony on PDA at 25C; B, reverse of same; C, 10-day-old colony on PDA at 20C; D, 14-day-old colony on PDA at 20C; E, 14-day-old colony on MEA at 25C; F, 10-day-old colony on MEA at 20C.

Phoma lycopersici has, in the past, because of possession of one-septate as well as unicellular conidia, been classified in the genera *Ascochyta* Lib. and *Diplodina* Westd., but because of a preponderance of unicellular conidia when grown *in vitro*, it is currently classified in *Phoma* rather than *Ascochyta*. It is, of course, quite unlike *D. microsperma* (Johnston) Sutton [= *D. salicis* Westd.], the type species of *Diplodina*.

TAXONOMIC PART

Phoma lycopersici Cooke, *Grevillea* 13: 94, 1885 (Plates 1 and 2, figure 1).

= *Sphaeronaema lycopersici* Plowr., *Gard. Chron.* 16: 260, 1881.

≡ *Ascochyta lycopersici* (Plowr.) Brun., *Bull. Soc. bot. Fr.* 34: 430, 1887.

≡ *Phoma lycopersici* (Plowr.) Jacz., *Nouv. Mem. Soc. Imp. Nat. Moscou* 15: 350, 1898.

= *Diplodina lycopersici* Hollõs, *Ann. Mus. Nat. Hung.* 5: 461, 1907.

[For additional synonyms, see Wollenweber and Hochapfel (1936) and Boerema and Dorenbosch (1973).]

Teleomorph: *Didymella lycopersici* Kleb., *Z. PflKr. PflPath. PflSchutz* 31: 12, 1921.

Colonies on potato dextrose agar (PDA) [Difco] (Plate 1, A & B) lanose to felty, pale gray to olivaceous gray to brownish, margin more or less even with a paler, usually whitish to cream marginal zone, 5-6 mm wide, irregularly zonate and frequently mottled with darker, brownish, orbicular, confluent patches, particularly at 20C, with age center becoming blackish but often with irregular paler patches, attaining a diameter of 78 mm at 20C, 30 mm at 25C, and 22 mm at 30C after 10 days; reverse black, sometimes irregularly mottled with paler areas. Ten-day-old colonies on PDA at 20C entirely white except for extreme center (Plate 1, C), becoming progressively darker with age; 14-day-old colonies (Plate 1, D) uniformly grayish or olivaceous brown or mottled with darker orbicular patches. In 21-day-old or older colonies, sterile stilboid aggregations of hyphae, which may assume a pseudoparenchymatous texture, frequently present. Colonies on malt extract agar (MEA) [Difco] (Plate 1, E & F) sparse, with little aerial mycelium in the form of thin whitish tufts, olivaceous, slightly striate, attaining a diameter of 75 mm at 20C, 40 mm at 25C, and 29 mm at 30C after 10 days. Colonies on cellulose agar after 20 days at 20C thin, with very little white aerial mycelium in the form of tufts but with abundant superficial or immersed black pycnidia. Mycelium composed of two kinds of hyphae: hyaline, smooth, branched, thin-walled, widely-septate, 2-3 um wide; and pale to mid-brown, smooth, branched, thicker-walled, closely-septate, 5-6.5 um wide (Plate 2, F). Wider, pigmented hyphae sometimes aggregated into strands of a few and, with age, individual cells often becoming slightly inflated. In 21-day-old colonies on PDA, a thin network of thick hyphae overlays the dense felted hyaline mycelium. Pycnidia produced on PDA and cellulose agar after two weeks [and on oatmeal agar, fide Boerema and Dorenbosch (1973)], usually originating from the wider, pigmented hyphae, immersed or entirely superficial, especially on PDA where they frequently form on the surface of the mycelial mat, scattered, gregarious or confluent in small groups of two or

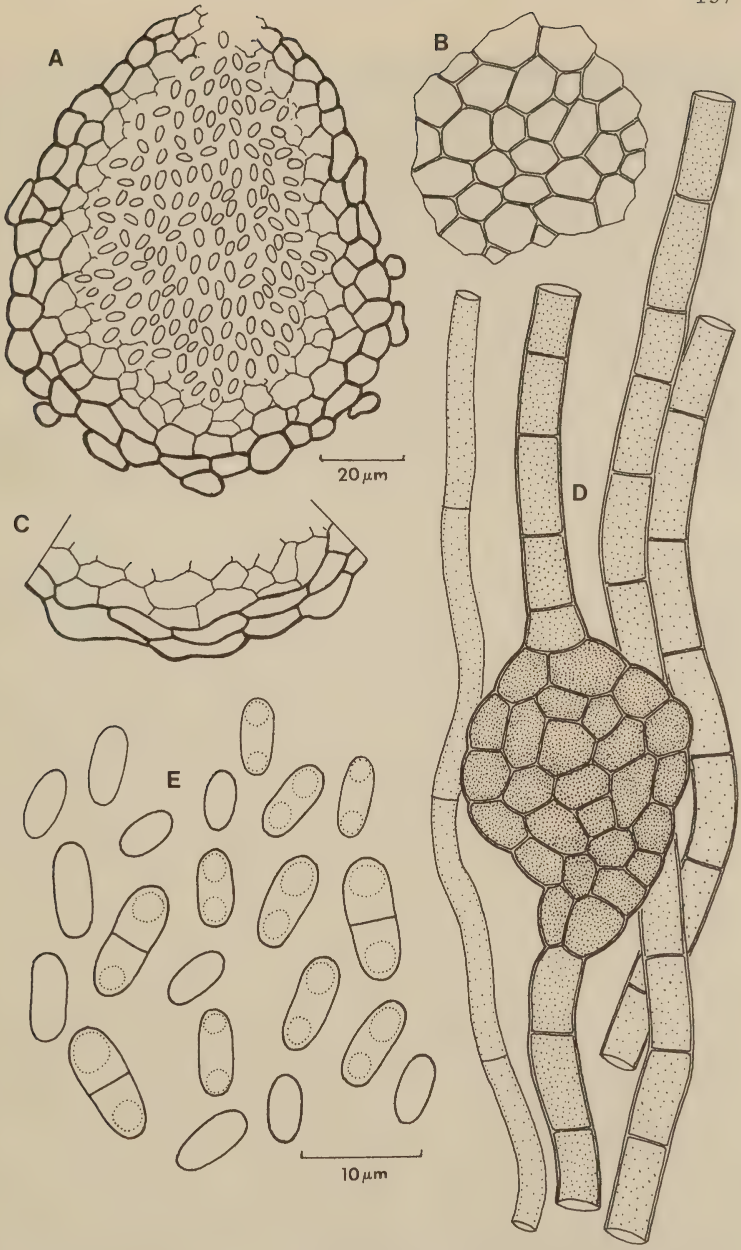


FIGURE 1. *Phoma lycopersici*. A, V.S. young pycnidium; B, surface view of portion of pycnidial wall; C, portion of wall of mature pycnidium in section; D, hyphae and pycnidium initial; E, conidia.

three, subglobose or elongate or somewhat irregular in shape, brown to blackish when mature, generally remaining paler above, pseudoparenchymatous, without a clearly defined ostiole, 120-210 um in diameter. Numerous small pycnidial rudiments, in addition to mature pycnidia, usually present in 21-day-old colonies on PDA and cellulose agar. Pycnidial wall composed of an outer layer, one to two cells thick, of ellipsoid to oblong, pigmented, thick-walled cells and an inner, wide layer of large, subglobose or irregularly-shaped, more or less isodiametric, hyaline, thin-walled cells. As pycnidia mature, the thick-walled, outer pycnidial wall cells become progressively flattened and somewhat contorted (Plate 2, D & E). Pycnidial initials at first made up of a solid mass of pseudoparenchymatous tissue, the central part of which eventually disintegrates to form the venter. Progressive lysis as pycnidia mature results in increase in size of the venter. In surface view, pycnidial wall cells appearing appreciably angular, of the "textura angularis" tissue type sensu Starbäck (1895). Ostiole lysigenous, formed by breakdown of cells at the pycnidial apex. Conidiogenous cells obscure, undifferentiated from other inner pycnidial wall cells. Conidia enteroblastic, hyaline, smooth, highly variable in shape and size, oblong to ellipsoid to obovoid, guttulate, unicellular or one-septate; when unicellular 3-9 X 2-3.5 um, when bicellular 6-11 X 3-4.5 um, and slightly constricted at the septa. Conidial masses whitish to cream-colored, sometimes with a yellowish tinge.

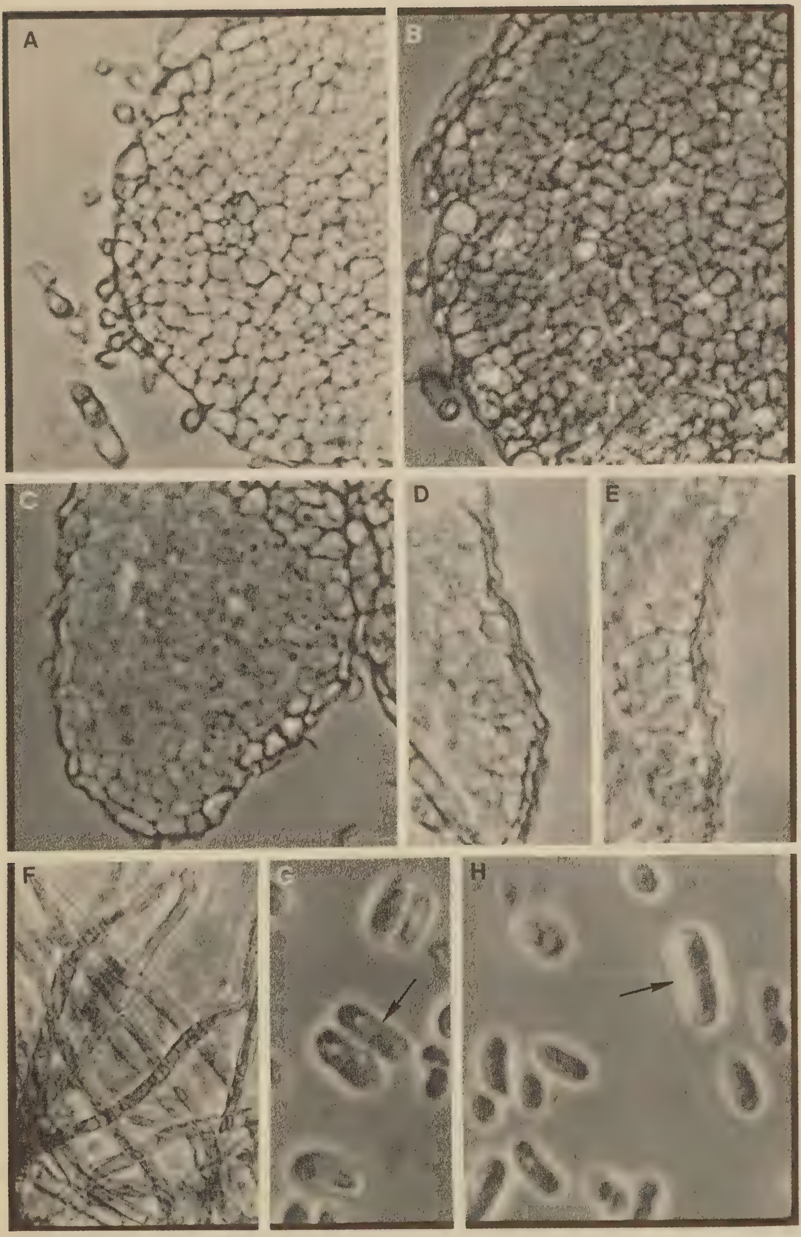
On *Lycopersicon esculentum*; cosmopolitan.

Collections examined: isolated from stem rot of tomato, Wageningen, The Netherlands, 1968, G.H. Boerema, PD, AUA; isolated from tomato stem, The Netherlands, G.H. Boerema, PD72/863, ATCC 24638, CBS 378.67 IMI17314.

DISCUSSION

As previously mentioned, several authors have provided descriptions of *P. lycopersici*. Brooks and Searle (1921), in an extensive investigation of tomato diseases, examined over twenty fungal isolates, originating mainly from rotting tomato fruit. Of these, six (designated series 2, forms E,F,J,L,M,P) were found to have relatively uniform characteristics and, together with six herbarium specimens, were determined to represent the same organism which was referred to as an "aggregate species". The isolates were described as having white to grayish colonies on Dox agar and to produce pycnidia bearing a small proportion of one-septate conidia in addition to unicellular ones. Four of the herbarium specimens, including the type material of *Phoma lycopersici* Cooke [on tomato stem, collected by J.E. Vize, circa 1884], originated in the Kew Herbarium. Three had been named *Mycosphaerella citrullina* (probably by G.E. Massee, since he had identified the causal organism of a disease of tomato submitted to him by F.T. Brooks as "*Ascochyta citrullina* C.O. Sm., the conidial form of *Mycosphaerella citrullina* Gross."). In the process of determining what name to apply to the fungus, various binomials were considered. *Diplodina* was chosen as the most appropriate generic name because of the presence of septate conidia. *Ascochyta* was considered unsuitable since pycnidia did not occur in spots. In spite of having examined the type of *Phoma lycopersici*, this

PLATE 2. *Phoma lycopersici*. A, surface view of part young pycnidium; B, surface view of older pycnidium; C, V.S. young pycnidium; D & E, portions of wall of mature pycnidia in section showing compressed outer cells; F, pigmented hyphae; G & H, conidia. [septae indicated by arrows].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name was disregarded with the cryptic comment "Cooke's name *Phoma lycopersici* is deleted". Both *Ascochyta lycopersici* (Plowr.) Brun. [as *A. lycopersici* Brun.] and *Sphaeronaema lycopersici* Plowr. were recognized as being possibly applicable, but Brooks and Searle seemed unaware of the fact that the former name is an obligate synonym of the latter. The binomial *A. lycopersici* was not taken up because, in their words, "it is preferable to place it (the fungus) in the genus *Diplodina*". *Sphaeronaema lycopersici* was eliminated because of an "apparent loss of the type specimen" and doubt on the part of the authors that C.B. Plowright had placed his fungus in the right genus since the neck of his figured pycnidium was extremely short. Having discarded three of the earlier names, the binomial *Diplodina lycopersici* Hollōs was adopted [as *Diplodina lycopersici* (Cooke) Hollōs emend. Brooks and Searle]. Three isolates (designated series 1, forms B, H and Q) from tomato fruits were matched with a culture of *Phoma destructiva* obtained from C.L. Shear (referred to as being 'authentic' presumably because it originated with B.O. Jamieson). These were distinguished from those to which the name *Diplodina lycopersici* was applied by, among other features, absence of septate conidia.

Klebahn (1921) distinguished *D. lycopersici* from *P. destructiva* on the basis of the former not producing mature pycnidia in agar culture, whereas the latter did so readily, but produced no septate conidia. The degree of pycnidial production and maturation do not, however, appear to be stable characteristics since Brooks and Searle (1921) noted one of their isolates of *P. destructiva* [Q] to produce few pycnidia and to sporulate sparsely on all media. In contrast to all investigators who have studied these two fungi *in vitro*, Grove (1935), who harbored a self-admitted aversion to cultures, considered them to be identical.

Wollenweber and Hochapfel (1936) provided an account of the variation in shape and size of conidia on different media and described the sterile "stilboid" bodies produced by *P. lycopersici in vitro*. Dennis (1946) described the cultural characteristics of an isolate from stem of a tomato plant (his strain 11), for which the name *Diplodina lycopersici* Hollōs was again used, on malt extract agar. No pycnidia matured on this medium but a dense layer of pycnidia was produced on sterilized potato plugs. The sterile "stilboid" bodies noted by Wollenweber and Hochapfel were said to be produced abundantly in three-week-old cultures.

A brief description of *P. lycopersici*, together with its teleomorph *D. lycopersici*, was published by Holliday and Punithalingam (1970) but no details, beyond ascospore and conidial dimensions, of its characteristics *in vitro* were given. Laundon (1971) provided a brief account of the comparative cultural characteristics of *P. destructiva*, *P. exigua* and *P. lycopersici* on a potato/yeast extract/dextrose agar in both light and dark at 25C. Few or no pycnidia were formed by *P. lycopersici* in the dark, whereas moderate pycnidial production occurred when light was provided. Boerema and Dorenbosch (1973) found that pycnidia of *P. lycopersici* are usually produced abundantly on oatmeal agar in daylight or under near-ultra violet illumination.

In our experience, *P. destructiva* and *P. lycopersici* are easily distinguished from *P. exigua* on cultural characteristics, particularly colony appearance. Colonies of *P. exigua* on PDA at 25C are highly distinctive with an irregularly lobed or scalloped margin, abundant pycnidial production giving a blackish coloration, and much faster growth than those of the other two species. Pycnidia of *P. exigua* frequently coalesce to form large, irregular structures and have a well-defined, though somewhat inconspicuous, ostiole internally lined with hyaline, papillate cells. *P. lycopersici* differs from *P. destructiva* in having generally denser, paler colonies on PDA and larger, sometimes septate conidia. It also produces sterile stilboid aggregations of hyphae, and has a different growth rate *in vitro*. *P. lycopersici* grows appreciably faster than *P. destructiva* at 20C on both PDA and MEA but much slower at 25C.

Pycnidial structure in *Phoma lycopersici* reflects the fact that it is the anamorph of *Didymella lycopersici*, a member of the family Venturiaceae. Pycnidial initials resemble ascostromata of pleosporaceous fungi in their internal organization. In the process of maturation ostioles are formed in much the same manner as in some pseudothecia. Although we have examined a number of sections, we are uncertain which cells are conidiogenous since there is no clear series of fertile cells lining the pycnidial venter at any one time as is the case in most other *Phoma* species. Many internal cells appear to break down and it seems possible that the protoplasts of such entities, or parts thereof, might round off and become converted into conidia. The considerable variation in shape and size of individual conidia may reflect this. We have not observed typical phialidic conidiogenous cells with thickened periclinal walls, indicating production of a succession of conidia from each, in *P. lycopersici*.

It is clear that the form-genus *Phoma* as presently constituted is a heterogeneous entity. Species such as *P. hoehnelii* van Kesteren [anamorph of *Leptosphaeria doliolum* (Pers.) Ces. & de Not.], *P. leonuri* Letendre [anamorph of *L. slovacica* Picb.], *P. lingam* (Tode) Desm. [anamorph of *L. maculans* (Desm.) Ces. & de Not.], *P. macdonaldii* Boerema [anamorph of *L. lindquistii* Frezzi], *P. peducularis* Fuckel, *P. rubefaciens* Togl., and *P. sydowii*, now classified in *Phoma* Sacc., sect. *Plenodomus* (Preuss) Boerema, van Kesteren & Loerakker are unrelated to other species classified in the genus. Similarly *P. lycopersici* must be considered to have little, if any, affinity with the majority of taxa classified in the genus. Whether or not a separate section of the genus should be established to accommodate it and similar species must await further studies.

Accounts of diseases of tomato caused by *Phoma lycopersici* have been given by Schoevers (1929), Liesau (1932), Orth (1939), Small (1940) and Sheard (1944). Hickman (1946) and Phillips (1956) discussed infection of outdoor tomato crops, the latter from soil-borne inoculum. The teleomorph state has rarely been found in nature (Hickman, 1944; Fisher, 1955).

ACKNOWLEDGMENTS

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RUST FUNGI (UREDINALES) ON THE GENUS HYPARRHENIA (POACEAE)

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ABSTRACT

Seventeen rust species are reported occurring on *Hyparrhenia* spp. (Poaceae). Five species are described as new, viz. *Puccinia aureocrassa* on *H. newtonii* from Zimbabwe, *P. estcourtensis* on *H. quarrei* from S. Africa, *P. hyparrheniiphila* on *H. bracteata* from Tanzania, *Uredo collinae* on *H. collina* from Kenya, and *Uromyces hyparrheniicola* on *H. dregeana* from S. Africa. *P. duthiae* is reported for the first time on *Hyparrhenia*. Thirty-four *H.* spp. are now known as hosts for rusts. On *H. filipendula*, *H. rufa*, and *H. hirta* six rust species have been found. *P. eritraeensis* has been found on 20 *H.* spp. A key to the rust species and a list of host-species combinations are provided.

INTRODUCTION

In his monograph on "The rust fungi on cereals, grasses and bamboos" Cummins (1971) listed eight taxa of rusts on the genus *Hyparrhenia* Anderss. ex Fourn., three of which inhabiting only this genus. Later Gjærum (1983) added three more species to the list, one of which was known only on *Hyparrhenia*.

Hyparrhenia belongs to the tribe Andropogoneae (Andropogonideae) of the Poaceae. In his monograph Clayton (1969) maintained 52 species divided in six sections. Most species are known only from Africa, but a few occur also in other continents, and there are relatively few reports of rusts on *Hyparrhenia* outside Africa.

The greater part of specimens dealt with in this paper belong to the Royal Botanic Gardens, Kew, and I am most indebted to the Director for allowing me to study them. A few specimens belong to the International Mycological

Institute, Kew (IMI), and a few to the herbaria of the Botanical Museums in Copenhagen (C) and Oslo (O), and I thank the curators for permission to examine the material.

My thanks go to Dr. B.C. Cummins, Dept. of Plant Pathology, University of Arizona, Tucson, AZ, for the great interest he has taken in this study, for his help and advice with the identification of the rust species, and together with Prof. D.M. Henderson, Inverewe Gardens, Poolema, Ross-Shire, for comments on the draft. I also thank Dr. R.W.G. Dennis, Royal Botanic Gardens, Kew, for checking names of localities and collectors, Prof. F. Roll-Hansen, NISK, AS-NLH, for many discussions, and Mrs. Rannveig Ødegaard, Norwegian Plant Protection Institute, for preparing the manuscript for publication.

ENUMERATION OF SPECIES

PHAKOPSORA INCOMPLETA (Syd.) Cumm., Mycologia 42: 786, 1950.

On *Hyparrhenia cymbaria* Stapf

Uganda. Masaka, near Mfrungwe, 1230 m, 27.06.1929, J.D. Snowdon (1390, C), II.

On *Hyparrhenia rufa* (Nees) Stapf

Malawi. Nyassa Hochland, Station Kyimbila, 1000 m, 27.06.1912, A. Stolz (O), II.

This rust has previously been reported only once on *Hyparrhenia*, viz. on *H. rufa* from Uganda, but it has been reported on several other host genera in Africa and Asia.

PUCCINIA ANDROPOGONICOLA Har. & Pat., Bull. Mus. Hist. Nat. Paris 1909: 199, 1909.

On *Hyparrhenia anamesa* W.D. Clayton

S. Africa. Cape Prov., George div., Kaaiman's River, 03.1952, M. Wilman (25479), II.

On *Hyparrhenia anthistirioides* (Hochst. ex A. Rich.) Anderss. ex Stapf (syn. *H. pseudocymbaria* (Steud.) Stapf)

Ethiopia. Eritrea, Sarae, by river Mareb, 06.10.1902, A. Palpi (409), (II+) III.

On *Hyparrhenia bracteata* (Willd.) Stapf

Thailand. Phu Kradung, 1300 m, 27.11.1958, Th. Sørensen, K. Larsen & B. Hansen (6264, C), II.

On *Hyparrhenia diplandra* (Hack.) Stapf

Nigeria. NE State, Mambilla plateau, Nguroje forest reserve, 1740 m, 12.12.1975, J.D. Chapman (4068), II.

On *Hyparrhenia dregeana* (Nees) Stapf ex Stent

Sudan. Didinga mts, Nagichot, 12.09.1940, S.G. Myers (13472), II.

On *Hyparrhenia familiaris* (Steud.) Stapf

Tanzania. Bukoba distr., Ngono bridge, 10.06.1934, H. Gillman (61A), II.

On *Hyparrhenia filipendula* (Hochst.) Stapf

Uganda. Hoima, Dweli, 02.1928, Dept. agric. (887), II.

Nigeria. Jos div., no date, W.J. Howard (960), II.

On Hyparrhenia involucrata Stapf
Nigeria. Zaria prov., Samanu, 600 m, 12.11.1948, D.V. Thatcher (537), III, and Samanu 670 m, 18.10.1947, W.E. Freeman (165), (II+) III.
On Hyparrhenia newtonii (Hack.) Stapf
Ruanda. Reg. Mutara, near Kokitumba, 1350 m, 24.05.1957, G. Troupin (3220, C), II.
On Hyparrhenia subplumosa Stapf
Ghana. Five miles S of Kologu, 12.11.1963, R. Rose Innes (3092), II + III.
Liberian-Guinea border, 11.11.1964, P. Adams (748), II.

P. andropogonicola, described on a species of Andropogon (Cymbopogon ?) from Congo, has been found widespread on a long series of Hyparrhenia species in Africa, and it has also been reported on H. rufa (Nees) Stapf from Cuba (Rosenada 1973), the only one outside Africa. H. anamesa, H. dregeana, H. involucrata, and H. subplumosa are all new hosts for this rust. Other African host genera are Andropogon, Cymbopogon, and Hyperthelia.

Specimens only with uredinia have spores with equatorial pores and a wall which is darker at the apex thus corresponding to the description given by Cummins (1971).

PUCCINIA ANDROPOGONIS-HIRTI Beltrán, Mem. R. Soc. Espan. Hist. Nat. 50: 252, 1921.
On Hyparrhenia arrhenobasis (Hochst. ex Steud.) Stapf
Ethiopia. Addis Ababa, 14.10.1977, coll. not given, II+III.
On Hyparrhenia cymbaria (L.) Stapf
Ethiopia. Ellubabon distr., Gumero, 10.01.1977, G. Awoke (1255), II(+III).
On Hyparrhenia dichroa (Steud.) Stapf
S. Africa. Transvaal, Kruger National Park, 7 miles NW of Punda Maria, 18.04.1950, L.E. Codd (5963), II(+III).
On Hyparrhenia dregeana (Nees) Stapf ex Stent
S. Africa. Natal, Estcourt, 1170 m 05.05.1945, J.H.P. Acocks (11498), II+III.

This rust has been described on H. hirta (L.) Stapf from Spain and later reported from Tunis, Corsica (France), and Turkey. A reexamination of a specimen from Madeira, published by Gjærum (1982) as P. hyparrheniicola Jørst. & Cumm., showed it to be P. andropogonis-hirti (telia present), new to Macaronesia. The hosts mentioned above are all new to the rust.

PUCCINIA AUREOCRASSA sp. nov. (Fig.1)

Aecidia ignota. Uredinia in pagina abaxiali foliorum, cinnamomea cum paraphysibus clavatis, leniter curvatis, usque 60 µm lateralibus, pariete hyalino, ad apicem usque 6.5 µm incrassato. Urediniosporae 20-29 x 23-27 µm, subgloboideae, ellipsoideae vel obovoideae, pariete 2-2.5 µm crasso, cinnamomeo, echinulato, 3-4 poris papillis humilibus tectis equatorialibus instructis. Telia in pagina abaxiali foliorum, exposita, fusca. Teliosporae ellipsoideae, saepe truncatae apicali vel aliquot diorchidioi-

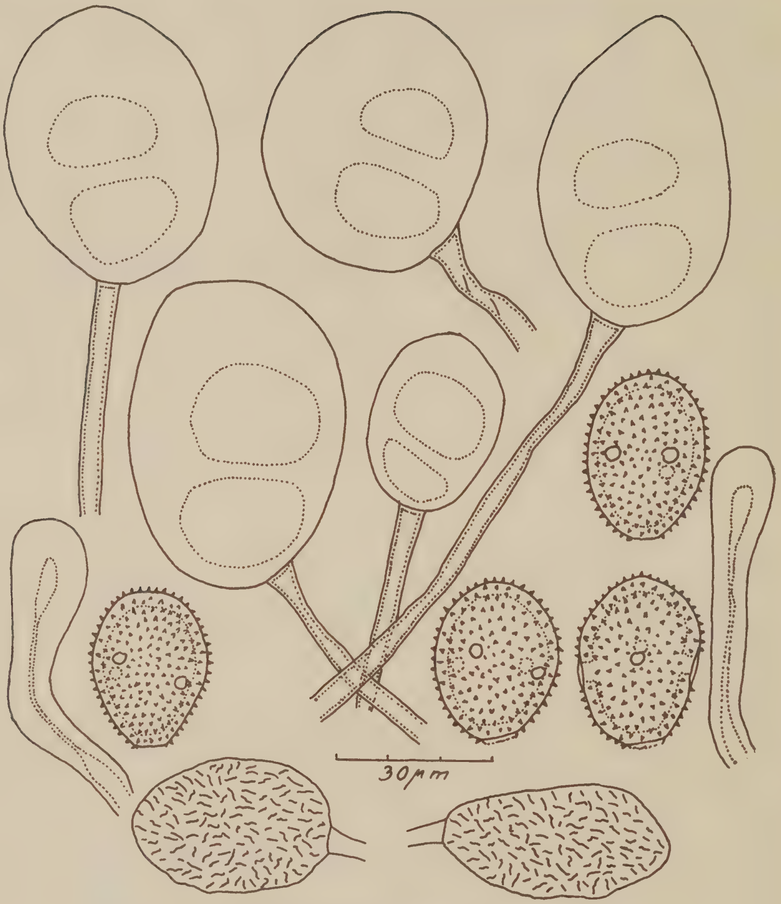

Fig. 1. Puccinia aureocrassa sp. nov.
a. Teliospores, b. The same teliospore before and after swelling. c. Urediniospores and paraphyses. d. Teliospores when partly dried after swelling (all from type).

deae, quum siccae 33-39 x 22-26 µm, fuscae, opaqae, rugosae, in liquido crescentes usque 41-55 x 31-42 µm, pariete 3-4 µm base, ad apicem usque 23 µm incrassato, aureo, pedicello usque 100 µm longo, pariete tenui, hyalino, collabente.
Holotype: V.M. Blackwell 2233 (K), Zimbabwe, Salisbury, 1450 m, 05.1920, on Hyparrhenia newtonii (Hack.) Stapf. Isotype in NPPI.

Other material examined:
On Hyparrhenia newtonii (Hack.) Stapf (incl. var. macra Stapf)
Malawi. Nyika approach, 25.05.1952, G. Jackson (856, C & K), (II+)III; Central Reg., Ncheu distr., Msese hill, 8 km N of Mlangeni, 30.04.1970, R.K. Brummit (10295), (II+)III.

The main feature of this rust species is the swelling of the teliospores. When dry it is very difficult to see whether the spore walls are rugose or smooth, when swollen in water or lactophenol they are smooth. This swelling takes place in most spores in a few seconds, increasing the size of the spores about 70% (Fig. 1b), measured in face view. When mounted in water which soon evaporates, the spores more or less shrink to normal size again, and show clearly the wrinkles on the wall (Fig. 1d).

P. aureocrassa differs from P. andropogonicola Har. & Pat., another rust on Hyparrhenia spp. with equatorial pores, having, when swollen, wider teliospores with a much thicker apical wall and lighter coloured wall. The urediniospores have fewer pores.

P. eylesii Doidge on Aristida spp. shows the same swelling phenomenon, but not as quickly and obviously as in P. aureocrassa. The teliospores of P. eylesii are more regularly ellipsoid or subgloboid.

Doidge (1950) listed ?H. newtonii as a host for P. rottboelliae Syd. (= P. levis (Sacc. & Bizz.) Magn. var. panici-sanguinalis (Rangel) Ramachar & Cumm.).

PUCCINIA DUTHIAE Ell. & Tracy in Ellis & Everhardt, Bull. Torrey Bot. Club 24: 283, 1897.
On Hyparrhenia bracteata (Willd.) Stapf
Sudan. Imatong mts, Gilo, near bridge across Ngarigi River, 13.11.1980, I. Friis & K. Vollesen (201, C), II+III.
On Hyparrhenia filipendula (Hochst.) Stapf
Malawi. Kasungu reserve, 990 m, 16.05.1970, A. Hall Martin (1775), II+III.
On Hyparrhenia subplumosa Stapf
Nigeria. Zaria Prov., Anara forest reserve, 20.10.1947, R.M.J. Keay (20109), II+III.

Hyparrhenia is a new host genus for this rust, previously known on Bothriochloa and Chrysopogon in Africa. In Asia and Australia Andropogon and Dichanthium have been reported as host genera. In India this rust was proved by Narasimhan (1965) to be host alternating with Barleria speciosa. (Acanthaceae, not listed in Index Kewensis).

Type host is Bothriochloa pertusa (L.) A. Camus (syn. Andropogon pertusus L.).

PUCCINIA ERITRAEENSIS Paz., Bot. Jahrb. 17: 14, 1893.
On Hyparrhenia anthistirioides (Hochst. ex A. Rich.) Anderss. ex Stapf
Ethiopia. Arussi Prov., near Dera, 1700 m, 03.10.1971, M. Thulin (1322), II+III; no loc. given, 23.09.1973, M.G. Gilbert (3133), III.

On *Hyparrhenia confinis* (Hochst. ex A. Rich.) Anderss. ex Stapf var. *nudiglumis* (Hack.) W.D. Clayton.

Sudan. Kordofan, Jebel Dair, Umm Ruwabe, 23.10.1952, J.K. Jackson (2412), (II+)III.

On *Hyparrhenia cyanescens* (Stapf) Stapf

Angola. Cuanza Norte, Cassualala railway station, 13.07.1921, Gossweiler (8813), II+III.

On *Hyparrhenia cymbaria* (L.) Stapf

Ethiopia. Kaffa Prov., at the road between Jimma and Bonga, 6.5 km SW of Jimma, 1750 m, 05.11.1970, I. Friis, A. Hounde & K. Jakobsen (121, C), II(+III).

Malawi. S. Region, Ndirande mt, 1220 m, 03.05.1970, R.K. Brummit (10344), II(+III).

Mozambique. Manica e Sofala, Spungubera, 08.06.1942, A.R. Torre (4262), II+III.

Zimbabwe. Wedza mts., 40 miles S of Monandellas, 1650 m, 21.05.1968, B.K. Simon et al. (1828), II+III.

Angola. Dugue de Braganza, Rianzando, by R. Lucala, 900 m, 01.09.1922, Gossweiler (8813), (II+)III.

On *Hyparrhenia diplandra* (Heck.) Stapf

French Guinea. No loc. given, 18.01.1955, G. Roberty, II+III.

On *Hyparrhenia mutica* W.D. Clayton

Mozambique. Zambesia, at R. Licungo, 20.11.1914, F.A. Mendonca (2129), II+III.

On *Hyparrhenia pilgerana* C.E. Hubbard

Ethiopia. Aghera mariam (Alghe) 30.11.1952, J.B. Gillett (14479), II+III; Sidamo, Bala, 2000 m, 05.01.1954, H.F. Mooney (5458), II+III.

Sudan. Imatong mts, between Konoro and Gilo, 24.11.1980, I. Friis & K. Vollesen (429, K&C), II+III.

Uganda. Kigezi, Chehiopi 1950 m, 15.10.1929, J.D. Snowden (1466), (II+)III.

On *Hyparrhenia quarrei* Robyns

S. Africa. Natal, Mt. Prospect, Newcastle, 09.05.1934, J.B. Pole Evans (3784), II(+III).

On *Hyparrhenia rudis* Stapf

Nigeria. Tiba plateau, Adamawa, 10.12.1965, K. Peter & P. Tuley (52), (II+)III.

On *Hyparrhenia rufa* (Nees) Stapf

Zambia. Central Prov., Lusaka distr., Lusaka, Olympia Park area, 1300 m, 01.09.1972, Arne Strid (2020, C), II+III.

On *Hyparrhenia schimperi* (Hochst. ex A. Rich.) Anderss. ex Stapf

Malawi. Ekwendeni distr., Mzimba, 1937, S.G. Wilson (18), II+III.

Zaire. Katanga, 8 km N of Elisabethville, 1300 m, 11.05.1964, J.J. Symoens (11005), II+III

On *Hyparrhenia subplumosa* Stapf

Sudan. Jebba, 35 m, 10.12.1927, O. Hagerup (721, C), (II+)III.

On *Hyparrhenia tamba* (Hochst. ex A. Rich.) Anderss. ex Stapf

S. Africa. Natal, Estcourt, 04.04.1945, J.P. Acocks (11492 or 11792), II+III (det. R.W.G. Dennis).

On *Hyparrhenia variabilis* Stapf

Uganda. No locality given, 08.1932, P. Chandler (913), II+III.
Tanzania. Morogoro distr., 03.09.1930, P.J. Greenway (2513), II+III.
Zambia. Mwinilunga, 31.05.1963, J.P. Loveridge (708), (II+)III.
Zimbabwe. Mazoe valley, 1050 m, 15.07.1950, S.M. Rattray (1556), (II+)III.
On *Hyparrhenia welwitschii* (Rendle) Stapf
Sudan. Fifteen miles N of Tambura, 04.10.1940, J.G. Myers (13530), (II+)III.

P. eritraeensis is widespread on *Hyparrhenia* spp. in Africa, and it has also been reported on *H. hirta* (L.) Stapf from Mallorca (Spain) and Socotra (People's Democratic Republic Yemen). Among the *Hyparrhenia* species mentioned above *H. anthistirioides*, *H. confinis*, *H. cyanescens*, *H. mutica*, *H. rudis*, and *H. tamba* are new hosts for this rust. In Africa it has been reported on *Cymbopogon*. Other host genera are *Andropogon*, *Capillipedium*, and *Trachypogon*, and it has been reported from Australia and Honduras.

Type host is *Andropogon* sp. from Eritrea (Ethiopia).

Without teliospores this rust can hardly be separated from *P. andropogonis-hirti* Beltrán and *P. hyparrheniicola* Jørst. & Cumm. (cf. Cummins 1971).

PUCCINIA ESTCOURTENSIS sp. nov. (Fig. 2)

Aecidia ignota. Uredinia in pagina abaxiali foliorum, cinnamomea, cum paraphysibus clavatis, raro capitatis, curvatis vel geniculatis, usque 90 µm longis, 14-26 µm latis, pariete ad apicem usque 8 µm crasso, hyalino vel pallido luteo. Urediniosporae 33-37 x (23-)27-41 µm, pariete 2-3 µm crasso, echinulato, (5-)6-7(-8) poris papillis humilibus tectis dispersis instructis. Telia in pagina abaxiali foliorum, exposita, fusca, saepe in urediniis evoluta. Teliosporae 42-52(-57) x 29-33 µm, ellipsoideae, ad septum leniter constrictae, pariete 3-4.5 µm, crasso, ad apicem 9 µm incrassato, laevi, cinnamomeo vel castaneo, poro superiore apicali, poro inferiore prope septum, obscuro, pedicello usque 90 µm longo, pariete tenui, hyalino vel pallido brunnneo, saepe collabente.
Other material examined:
On *Hyparrhenia finitima* (Hochst.) Anderss. ex Stapf
Malawi. Nyassa Hochland, Station Kyimbila, 1000 m, 12.06.1912, H. Stolz (1352, 0), II+III.

This rust differs from *P. eritraeensis* Paz. in having larger teliospores with thicker walls both at the sides and apically, and also somewhat larger urediniospores with thicker, not so strongly pigmented walls.

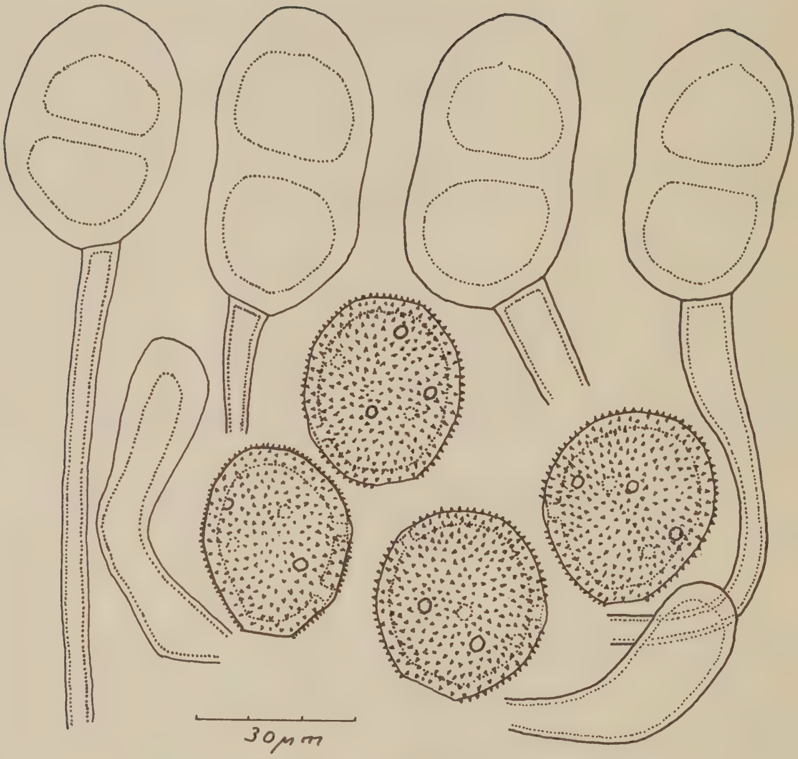

Fig. 2. *Puccinia estcourtensis* sp. nov.
Teliospores, urediniospores and paraphyses
from type.

PUCCINIA EUCOMI Doidge, Bothalia 3: 497, 1939.
On *Hyparrhenia niariensis* (Franch.) W.D. Clayton
Zaire. Kisantu, 15.05.1952, H. Callens (3610A), II;
Kisantu, Lendahenda, 15.04.1953, H. Callens (1266), II+III.
On *Hyparrhenia nyassae* (Rendle) Stapf
Zimbabwe. Salisbury, 05.05.1934, H.B. Gilliland (62), II.
On *Hyparrhenia welwitschii* (Rendle) Stapf
Nigeria. N.W. State, 5 miles S of Abiya, 11.11.1974, A. Blair Rains (249), (II+)III.

P. eucomi has been reported on *Hyparrhenia filipendula* (Hochst.) Stapf from Uganda. The three hosts mentioned above are all new to the rust which elsewhere has been reported on *Andropogon eucomus* Nees (type host) and *A. huillensis* Rendle from S. Africa.

PUCCINIA HYPARRHENIAE Cumm., Bull. Torrey Bot. Club 83: 226, 1956
On _Hyparrhenia cymbaria_ (L.) Stapf
Malawi. Zomba mt, 18.08.1950, P.O. Wiehe (612), II+III.

H. cymbaria is a new host for this rust, described on _H. rufa_ (Nees) Stapf from Malawi. Later it has been reported from Uganda. Other hosts are _H. dregeana_ and _H. variabilis_.

PUCCINIA HYPARRHENIICOLA Jørst. & Cumm. in Cummins, Bull. Torrey Bot. Club 8: 227, 1956.
On _Hyparrhenia nyassae_ (Rendle) Stapf
Zimbabwe. Gwelu, 1380 m, 19.04.1967, H.M. Biegel (2077), (II+)III.
On _Hyparrhenia rufa_ (Nees) Stapf
Nigeria. Saman, 11.1983, V. Sekar (IMI 285923), (II+)III.

The two hosts mentioned above are both new for this rust, previously known only from _H. hirta_ (L.) Stapf, all belonging to the section Polydistachyophorum (Gren. & Godr.) W.D. Clayton. The rust on _H. rufa_ has somewhat longer and narrower teliospores than quoted in the diagnosis, 37-57 x 13-18 µm, but when studying the isotype of the species (O) I found teliospores measuring up to 58 µm long. The rust on _H. nyassae_ has slightly lighter coloured urediniospore wall, but this might depend on age.

P. hyparreniicola, described from the Canary Islands, has previously been reported only from Macaronesia, but as very often only uredinia are present and _P. andropogonis-hirti_ Beltrán now is known from Madeira, there might be some doubtful records.

PUCCINIA HYPARRHENIIPHILA sp. nov. (Fig. 3)

Aecidia ignota. Uredinia in pagina abaxiali foliorum, cinnamomea cum paraphysibus clavatis, curvatis vel geniculatis, usque 62 µm longis, 8-13 µm latis, pariete ad apicem usque 4 µm crasso. Urediniosporae 20-25 x 17-21 µm, subgloboideae, ellipsoideae vel angulatae, pariete 1-1.5 µm crasso, ad apicem usque 2-2.5 µm incrassato, castaneo, echinulato, (3-)4 poris papillis humilibus tectis equatorialibus instructis. Telia in pagina abaxiali foliorum, exposita, fusca. Teliosporae 38-47 x 26-36 um, ellipsoideae vel obovoideae, saepe diorchidioideae, pariete 2-4.5 µm crasso, ad apicem usque 14 µm incrassato, cinnamomeo vel castaneo, laevi, poro superiore apicali, poro inferiore obscuro, pedicello usque 90 µm longo, pariete luteolo, tenui, saepe collabente.
Holotype: R.M. Davies 822 (K), Tanzania, Iringa Prov., Mufindi, 1950 m, 15.10.1937, on _Hyparrhenia bracteata_ (Willd.) Stapf. Isotype in NPPI.
Other material:
On _Hyparrhenia bracteata_ (Willd.) Stapf
Sudan. Imatong mts, Gilo, 13.11.1980, I. Friis & K. Vollesen (201), II.
Zaire. Orientale Prov., Mahagi, Nioka, 15.12.1956, D.

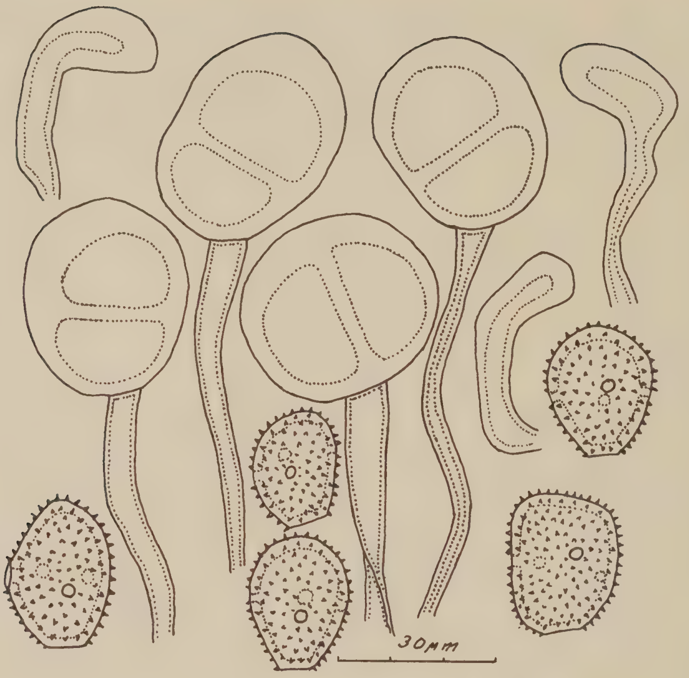

Fig. 3. Puccinia hyparrheniiphila sp.nov. Teliospores, urediniospores and paraphyses from type.

Froment (51), II.
On Hyparrhenia filipendula (Hochst.) Stapf
Zimbabwe, Sibu, 10 miles W of Melsetter,. 19.06.1953, A.O. Crook (477), II+III.
On Hyparrhenia newtonii (Hack.) Stapf
Tanzania. Keza, 1470 m, 05.1950, G. Watkins (422), II-(+III).
Angola. Nova Lisboa - Caala, 1650 m, 06.03.1973, P. Bamps et al. (4010), II.

P. hyparrheniiphila differs from P. andropogonicola Har. & Pat. in having smaller urediniospores with thinner walls and shorter, but wider teliospores with shorter, yellowish, often collapsing pedicels.

PUCCINIA LEVIS (Sacc. & Bizz.) Magn. var. PANICI-SANGUINALIS (Rangel) Ramachar & Cumm., Mycopath. Mycol. Appl. 25: 44, 1965.

Doidge (1950) reported this variety as P. rottboelliae

P. & H. Syd. on "?Hyparrhenia newtonii Stapf" and later Hopkins (1938) reported it from Zimbabwe on the same host. It is widespread in Africa, especially on Rottboellia spp., but it has also been reported on Brachiaria brizanta (A. Rich.) Stapf and Hemarthria sp. Rudbeckia sp. (Asteraceae) have been reported as aecial hosts in Zambia (Angus 1966), but this is not mentioned by Cummins (1971).

Outside Africa it is known on species of Ichnanthus, Panicum, Paspalum, Pennisetum, Reimarochloa, and Sorghastrum, and it is known in Asia and the Americas.

Type host is Panicum sanguinale L. from Brazil.

PUCCINIA VERSICOLOR Diet. & Holw. in Holway, Bot. Gaz. 24: 28, 1897.

On Hyparrhenia collina (Pilg.) Stapf
Ethiopia. Simien Prov., Agrima, 1800 m, 09.1851, W. Schimper (138), II.
On Hyparrhenia cymbaria (L.) Stapf
Tanzania. Tanganyika terr., Ubosi, Komora Estate, 1929, Mrs. Axel Jacobsen (C), II.
Zambia. Lusaka, 17.06.1972, K. Kornas (1914), II+III.
Zaire. Kivu, Kalonge, 16.02.1953, H.E. de Witte (10306), II+III.
On Hyparrhenia dichroa (Steud.) Stapf
Malawi. Citala, 26.04.1951, G. Jackson (480), II.
On Hyparrhenia dregeana (Nees) Stapf ex Stent
Ethiopia. Arussi Prov., Chilalo awraja, 5 km N of Asella, 15.11.1971, M. Thulin (1680), II+III.
On Hyparrhenia madaropoda W.D. Clayton
Zaire. Ruzizi plain, Kiliba, 850 m, 13.03.1960, F.L. Hendrickx (7617), II.
On Hyparrhenia nyassae (Rendle) Stapf
Zimbabwe. Makurro, 04.1920, C. Mainwarny (2203), II.
On Hyparrhenia pilgerana C.E. Hubbard
S. Africa. Natal, Lion's river distr., Benvie, no date, K.D. Gordon Gray (2930), II.
On Hyparrhenia rudis Stapf
Sudan. Jebel Marra, 1740 m, 07.04.1964, G.E. Wickens (1457A), II+III.
On Hyparrhenia rufa (Nees) Stapf
Uganda. Murchison Falls Park, 15.09.1967, A. Angus (5977), II.
Sierra Leone. Musaia, 28.02.1946, F.C. Deighton (4205), II.
On Hyparrhenia smithiana (Hook.f.) Stapf
Cameroon. Road to Oku, 1840 m, 22.06.1962, M. Brunt (652), II.
On Hyparrhenia smithiana (Hook.f.) Stapf var. major W.D. Clayton
Nigeria. Tiba plateau, Adamawa, 10.12.1965, K. Peter & P. Tuley (62), II+III.
On Hyparrhenia variabilis Stapf
Tanzania. Mbeya, 06.1938, L. Wigg (1194), (II+)III.
Zambia. Lusaka, 1270 m, 17.06.1972, J. Kornas (1913), II+III.
On Hyparrhenia welwitschii (Rendle) Stapf

Malawi. Zomba, 930 m, 14.05.1940, P.O. Wiehe (103), (II+)III.
Zimbabwe. Mukunze, 40 miles W of Mporokoso, 1300 m, 13.04.1961, D.E.F. Vesey-Fitzgerald (3144), (II+)III.
Sierra Leone. Musaia, 17.12.1946, F.C. Deighton (4433), III.
Angola. Lunda, Henrique de Carvalho, 1015 m, 04.1937, Gossweiler (11540), III.

P. versicolor is widespread in Africa, in Asia east to Japan.

P. versicolor has previously been reported on several Hyparrhenia spp. from Ethiopia to S. Africa. New hosts are H. collina, H. cymbaria, H, dichroa, H. nyassae, H. rudis, and H. smithiana s.lat.

It inhabits a number of other genera in Africa, Asia, Australia, and the Americas, and it is also reported from Mallorca (Spain).

Type host is Heteropogon melanocarpus (Ell.) Benth. from Mexico.

Due to its hyaline urediniospores with a stellate lumen P. versicolor is quite easily recognized even when only uredinia are present.

The aecial stage, Aecidium plectroniae Cooke, occurs on species of Canthium (incl. Plectronia) and Lantana (Rubiaceae).

A specimen (IMI 178445) previously published by Ebbels (1974) and Ebbels & Allen (1979) as P. eritraeensis Paz. on H. madaropoda from Tanzania must be transferred to P. versicolor due to lack of paraphyses in the uredinia and with colourless urediniospores with a stellate lumen.

UREDO COLLINAE sp. nov. (Fig. 4)

Uredinia amphigena, pro maxima parte in pagina abaxiali foliorum, cinnamomea. Urediniosporae 20-27 x 20-23 µm, subgloboideae vel ellipsoideae, pariete 3-4.5 µm crasso, cinnamomeo, echinulato, 6-8 poris dispersis instructis.
Holotype: G.R. Williams 137 (K), Kenya, Eldoret distr., 2100 m, 26.04.1951, on Hyparrhenia collina (Pilger) Stapf.
Isotype in NPPI.

This species differs from the other species without paraphyses on Hyparrhenia, Uromyces clignyi Pat. & Har., by having urediniospores with a much thicker wall.

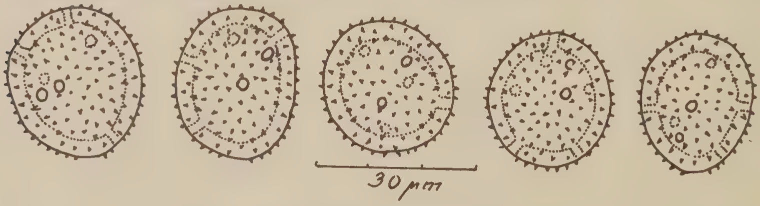

Fig. 4. Uredo collinae sp. nov.
Urediniospores from type.

UREDO sp.
On *Hyparrhenia dregeana* (Nees) Stent
S. Africa. Transvaal, 9 miles W of Krugersdorf, 22.02.1948, R.J. Rodin (3822)
On *Hyparrhenia hirta* (L.) Stapf
Algeria. Algiers, 10.1878, M. Gandoger (170).
Morocco. Tanger, 25.08.1926, H. Lindberg (1289).
On *Hyparrhenia newtonii* (Hack.) Stapf
Malawi. Fort Manning, 21.04.1952, G. Jackson (769).
On *Hyparrhenia pilgerana* C.E. Hubbard
Ethiopia. Bongo, 1800 m, 22.12.1965, G.J.H. Amshoff (9444).
Uganda. Kigezi, Nakishenyi, 04.02.1928, L.C.C. Liebenberg (395); Bufumbira distr., Kisoro, 1800 m, 13.02.1945, P.J. Greenway & W.S. Eggeling (7130).
S. Africa. Natal, Pietermaritzburg distr., 17.03.1976, J. Lee (2930).
On *Hyparrhenia quarrei* Robyns
S. Africa. Natal, Pietermaritzburg distr., Thornville Junction, 26.03.1976, J. Lee (2930 B).
On *Hyparrhenia rufa* (Nees) Stapf
S. Africa. Transvaal, Letaba distr., 960 m, 01.04.1958, J.C. Scheepers.
On *Hyparrhenia schimperi* (Hochst. ex. A. Rich.) Anderss. ex Stapf
Uganda. Miyemba near Mt Elgon, 1200-1500 m, 15.08.1927, J.D. Snowden (1168).
On *Hyparrhenia smithiana* (Hook.f.) Stapf
Nigeria. Bambui 12.1945, J.W.R. Pedder.
On *Hyparrhenia variabilis* Stapf
Zaire. Leopoldville, 06.1957, R.E. Delhaya (119).

The specimens mentioned above have all uredinia with clavate, curved or geniculate, hyaline to golden paraphyses and spores, 22-31 x 19-25 µm, with (5-)6-8(-9) scattered pores. The wall is 1.5-2.5 µm thick, mostly chestnut-brown.

Some of the specimens might belong to *Puccinia eritraeensis* Paz. or *P. andropogonis-hirti* Beltrán, but as they hardly can be separated when only uredinia are present, I prefer to place them here under *Uredo* sp.

UROMYCES CLIGNYI Pat. & Har., J. Bot. 14: 237, 1900.
On *Hyparrhenia anthistirioides* (Hochst. ex A. Rich.) Anderss. ex Stapf (syn. *H. pseudocymbaria* (Steud.) Stapf)
Ethiopia. Ghibe, 29.09.1964, D. Yirgou (IMI 116533), (II+)III.

This rust species occurs on several host genera in Africa, Asia and the Americas. On *Hyparrhenia* spp. it has previously been reported on *H. hirta* (L.) Stapf, *H. papillipes* (A. Rich.) Stapf, and *H*. sp. The type host is given only as belonging to Andropogoneae from Moyen Congo (now in Mali). Cummins (1971) has given *Chlorophytum* (Liliaceae) as aecial host (*Aecidium hartwegiae* Thuem.), but also *Crinum* (Amaryllidaceae) has been reported (Patil & Thirumalachar 1969).

UROMYCES HYPARRHENIAE Gjærum, Mycotaxon 18: 229, 1983.
On *Hyparrhenia anamesa* W.D. Clayton
Ethiopia. Sidamo, Yavello, 2150 m, 11.01.1954, Mooney (5511), II+III.
On *Hyparrhenia familiaris* (Steud.) Stapf
Angola. Lunda, Muriego, 1100 m, 04.1937, Gossweiler (11710), II.
On *Hyparrhenia nyassae* (Rendle) Stapf
Cameroon. Dzerkoka, 13 km NW of Belal, 1540 m, 08.12.1964, J. & A. Raynal (12355), II+III.

U. hyparrheniae was described from Uganda on *H. filipendula* (Hochst.) Stapf. The hosts mentioned above are all new to this rust species.

UROMYCES HYPARRHENIICOLA sp. nov. (Fig. 5)

Aecidia ignota. Uredinia amphigena, linearia, cinnamomea cum paraphysibus clavatis, curvatis vel geniculatis, usque 80 µm longis et 12 µm lateralibus, pariete hyalino, ad apicem usque 5 µm incrassato. Urediniosporae 28-35 x 23-31 µm, ellipsoideae vel subgloboideae, pariete 1.5-2.5 µm crasso, dense echinulato, 7-9 poris papillis humilibus tectis dispersis instructis. Telia ignota. Teliosporae 15-23 x 12-16 µm, in urediniis evolutae, obovoideae, ellipsoideae vel angulatae, pariete 1 µm crasso, ad apicem usque 7 µm incrassato, laevi, pallide cinnamomeo vel cinnamomeo, poro apicali, pedicello usque 30 µm longo, pariete tenui, hyalino, collabente.

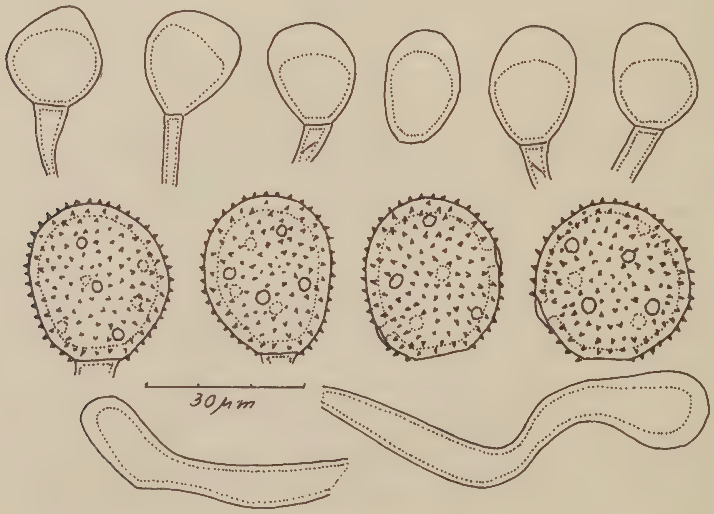

Fig. 5. *Uromyces hyparrheniicola* sp.nov. Teliospores, urediniospores and paraphyses from type.

Holotype: Pole Evans 703 (K), S. Africa, Transvaal, Pienaar's River, 02.03.1923, on *Hyparrhenia dregeana* (Nees) Stent. Isotype of II in NPPI.

The two *Uromyces* species previously known on *Hyparrhenia*, viz. *U. clignyi* Pat. & Har. and *U. hyparrheniae* Gjærum, both lack uredineal paraphyses. The new species differs from *U. aristidae* in having clavate, incurved, sometimes geniculate paraphyses and shorter teliospores with heads more abruptly thinned wall below. The host *Aristida arizonica* Vasey, the only host known of *U. aristidae*, belongs to the Eragrostoideae of Poaceae.

GENERAL REMARKS

On the genus *Hyparrhenia* seventeen rust species are recorded, seven of which are on *Hyparrhenia* only. In the literature available to me and from my own investigation these seventeen species are recorded on 34 *H.* species belonging to sect. II-VI in the system used by Clayton (1969).

In the table, 11 host species belong to the sect. II, 12 to sect. III, and five to sect. IV, while only one belongs to sect. V and four to sect. VI.

On *H. filipendula*, *H. hirta*, and *H. rufa* six rust species have been recorded, and *H. nyassae* and *H. cymbaria* both have five rust species. Ten *H.* spp. have only one rust each.

P. eritraeensis has been reported on 20 *H.* spp. belonging to the sect. II, III, and VI, and *P. versicolor* on 17 *H.* spp. belonging on the sect. II-V, while two other rust species are known to occur only on one *H.* species each.

Inoculation experiments might show whether the other *H.* spp., including sect. I, are resistant to the rusts hitherto known on the genus or it is due to the lack of material.

Aecial stages have been reported for four of the seventeen rust species living on *Hyparrhenia* spp., viz. *P. duthiae*, *P. versicolor* var. *panici-sanguinalis*, *P. versicolor*, and *Urom. clignyi*.

Key to the rust species with telia on Hyparrhenia
(based on Cummins 1971)

1. Teliospores sessile	Phaksopsora incompleta
1. Teliospores pedicellate (2)	
2. Teliospores 1-celled (3)	
2. Teliospores 2-celled (5)	
3. Uredinia paraphysate	Uromyces hyparrheniicola
3. Uredinia aparaphysate (4)	
4. Urediniospores with 4-7 pores	Uromyces hyparrheniae
4. Urediniospores with 7-10 pores	Uromyces clignyi
5. Uredinia aparaphysate (6)	
5. Uredinia paraphysate (9)	
6. Urediniospore wall coloured	Puccinia levis var. panici-sanguinalis
6. Urediniospore wall colourless (7)	
7. Urediniospore lumen stellate	Puccinia versicolor
7. Urediniospore lumen not stellate (8)	
8. Urediniospore apex thickened to 10-19 µm	Puccinia hyparrheniae
8. Urediniospore apex thickened to 5-9 µm	Puccinia eucomi
9. Urediniospores with equatorial pores (10)	
9. Urediniospores with scattered pores (13)	
10. Urediniospores thickened apically	Puccinia hyparrheniiphila
10. Urediniospores not thickened apically (11)	
11. Teliospores swelling in liquid	Puccinia aureocrassa
11. Teliospores not swelling (12)	
12. Urediniospores with equatorial pores (13)	
12. Urediniospores with scattered pores (14)	
13. Teliospores 35-41 µm long	Puccinia duthiae
13. Teliospores 40-56 µm long	Puccinia andropogonicola
14. Teliospores pedicel thick-walled	Puccinia andropogonis-hirti
14. Teliospore pedicel thin-walled (15)	
15. Teliospores up to 57 µm long	Puccinia estcourtensis
15. Teliospores scarely exceeding 40 µm (16)	
16. Teliospores mostly 33-40 x 20-27 µm	Puccinia eritraeensis
16. Teliospores mostly 33-40 x 16-10 µm	Puccinia hyparrheniicola

Tab. Rust species on Hyparrhenia spp.

Hyparrhenia	Sect.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
anamesa	II		x													x			2
anthistirioides	III		x				x								x				3
arrhenobasis	V			x										x					2
bracteata	VI		x			x						x							3
collina	III						x							x				x	3
confinis	IV						x							x					2
cyanescens	III						x												1
cymbaria	III	x		x			x			x				x					5
dichroa	II			x										x					2
diplandra	VI		x				x			x									3
dregeana	III		x	x										x			x		4
familiaris	II		x													x			2
filipendula	II		x			x	x		x			x				x			6
finitima	II				x														1
hirta	II		x	x			x				x			x	x				6
involucrata	II		x																1
madaropoda	IV													x					1
mutica	VI						x												1
newtonii	IV		x		x							x	x						4
niariensis	IV								x										1
nyassae	II						x		x		x			x		x			5
papillipes	III						x							x	x				3
pilgerana	III		x				x							x					3
quarrei	II						x	x											2
rudis	III						x							x					2
rufa	II	x	x				x			x	x			x					6
schimperi	III						x												1
smithiana	II													x					1
subplumosa	VI		x			x	x												3
tamba	III						x												1
umbrosa	III													x					1
variabilis	III		x*				x			x				x					4
welwitschii	IV						x		x					x					3
No. of hosts for each rust species		2	14	5	2	3	20	1	4	4	3	3	1	17	3	4	1	1	

* host uncertain

1 = Phakopsora incompleta
2 = Puccinia andropogonicola
3 = Puccinia andropogonis-hirti
4 = Puccinia aureocrassa
5 = Puccinia duthiae
6 = Puccinia eritraeensis
7 = Puccinia estcourtensis
8 = Puccinia eucomi
9 = Puccinia hyparrheniae
10 = Puccinia hyparrheniicola
11 = Puccinia hyparrheniiphila
12 = Puccinia levis var. panici-sanguinalis
13 = Puccinia versicolor
14 = Uromyces clignyi
15 = Uromyces hyparrheniae
16 = Uromyces hyparrheniicola
17 = Uredo collinae
18 = No. of rusts for each H. species

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ADDITION

After this paper had been sent to the Editor, I got a few more specimens on _Hyparrhenia_ with rusts, of which a few showed to be new hosts for the rusts in question.

PUCCINIA ANDROPOGONIS-HIRTI Beltrán
On _Hyparrhenia cymbaria_ Stapf
S. Africa. Natal, Pietermaritzberg, 14.09.1969, R.A. Stray (9053, K), II+III; Zululand, Ershowe, 04.1941, A.P.D. Maclean (983, K), II(+III).

PUCCINIA AUREOCRASSA sp. nov.
On _Hyparrhenia_ sp.
Zimbabwe. Salisbury, Springs, 13.06.1931, J.C. Hopkins (1627, K), II+III.

PUCCINIA VERSICOLOR Diet. & Holw.
On _Hyparrhenia papillipes_ (Hochst. ex A. Rich.) Anderss. ex Stapf
Sudan. Nyuringa, on the W side of Marra mts, 2000 m, 06.01.1934, J.E. Dandy (742, K), (II+)III.
On _Hyparrhenia umbrosa_ (Hochst.) Anderss. ex W.D. Clayton
Sudan. Between Guldu and Nyuringa, on W side of Marra mts, 1550-2050 m, 03.01.1934, J.E. Dandy (745, K), (II+)III.

MYCOTAXON

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CAMPOSPORIDIUM, A NEW PHRAGMOCONIDIAL GENUS OF HYPHOMYCETES

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Camposporidium cristatum sp.nov., type of a new genus, is described from submerged decaying leaves collected from several freshwater streams in Malaysia. The generic characters are compared with those of similar genera: **Camposporium, Chaetendophragmia, Pleiochaeta** and **Sporidesmium.**

Camposporidium gen.nov.

Coloniae effusae, sparsae, brunneae. Mycelium partim superficiale, partim in substrato immersum. Conidiophora macronematosa, mononematosa, solitaria, erecta, simplicia, recta vel flexuosa, cylindrica, septata, brunnea vel atrobrunnea, basi inflata, in primis brevia. Cellulae conidiogenae holoblasticae, monoblasticae, in conidiophoris incorporatae, terminales, cylindricae, proliferationis percurrantes. Conidia acrogena, solitaria, sicca schizolytice secendentia, cylindrica, multiseptata, ad apicem rotundata, ad basim truncata, colorata, apice appendicibus.

Species typica **Camposporidium cristatum.**

Colonies effuse, sparse, brown. Mycelium partly superficial, partly immersed in the substratum. Conidiophores macronematous, mononematous, solitary, erect, simple, straight to flexuous, cylindrical, septate, brown to dark brown, basally inflated, at first short. Conidiogenous cells holoblastic, monoblastic, incorporated in the conidiophores, terminal, cylindrical, proliferating percurrently. Conidia acrogenous, solitary, dry, seceding schizolytically, cylindrical, multiseptate, slightly tapered at the rounded apex, truncate at the base, coloured, apical cell bearing several long colourless, thin appendages.

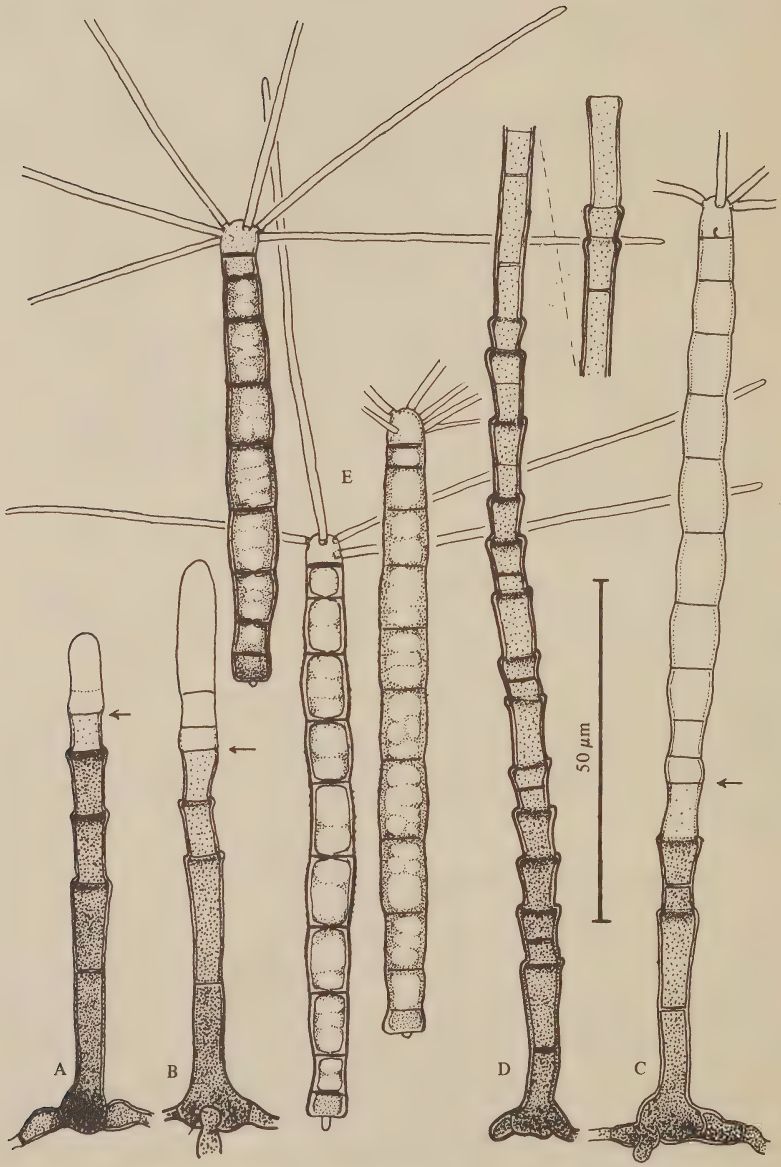

Fig.1. **Camposporidium cristatum.** (A – C) Conidiophores bearing conidia at various stages of development; (D) a conidiophore showing proliferations; (E) conidia.

Camposporidium cristatum sp.nov. Figs 1 – 2

Coloniae effusae, sparsae, brunneae, inconspicuae. Mycelium plerumque superficiale sed in substrato partim immersum, ex hyphis ramosis, septatis, pallide brunneis ad brunneis, laevibus, 1.5 – 2.5 µm latis compositum. Conidiophora macronematosa, mononematosa, erecta, solitaria, simplicia, recta vel leviter flexuosa, cylindrica, laevia, septata, brunnea ad atrobrunnea, ad apicem pallidiora, primo 30 – 45 µm alta, deinde usque ad 245 µm alta, 4 – 5 µm lata, ad basim saepe inflata ad 18 µm lata, per usque ad 25 non numquam etiam plures cylindricae proliferationes crescentia. Cellulae conidiogenae holoblasticae, monoblasticae, in conidiophoris incorporatae, terminales, cylindricae, proliferationes percurrantes. Conidia acrogena, solitaria, sicca, schizolytica secendentia, cylindrica, ad apicem rotundata, ad basim truncata, 9 – 12 distoseptata, verruculosa, olivacea vel olivaceobrunnea, 75 – 94 µm longa, 9 – 10 µm lata, ad basim 6 – 7 µm lata; apice 4 – 7 appendicibus usque ad 60 µm longis, 1.5 µm latis praedita, nonseptata, hyalina vel subhyalina.

In foliis emortuis submersis angiospermae, Lepar Forest Reserve, Pahang, Malaysia, A.J. Kuthubutheen, July 1986, IMI 321460 holotypus.

Colonies effuse, sparse, brown, inconspicuous. Mycelium mostly superficial but partly immersed in the substratum, composed of branched, septate, pale brown to brown, smooth 1.5 – 2.5 µm wide hyphae. Conidiophores macronematous, mononematous, erect, solitary, straight or slightly flexuous, smooth, septate, brown to dark brown, paler towards the apex, initially 30 – 45 µm high, finally up to 245 µm or more long, 4 – 5 µm wide, often swollen at the base to 18 µm wide, with up to 25 or more distinct percurrent proliferations along its length. Conidiogenous cells holoblastic, monoblastic, integrated, terminal, cylindrical, proliferating percurrently. Conidia acrogenous, solitary, dry, seceding schizolytically, cylindrical slightly tapered at the rounded apex, truncate at the base, 9 – 12 distoseptate, verruculose, olivaceous to olivaceous brown, 75 – 94 µm long, 9 – 10 µm at the widest part, 6 – 7 µm wide at the base, apical cell bearing 4 – 7 divergent, non-septate, hyaline to subhyaline appendages measuring up to 60 µm long x 1.5 µm wide.

Other specimens examined: On submerged decaying leaves of angiosperm, Pasuh Forest Reserve, Negri Sembilan, A. Nawawi, 10 Dec. 1986; Gombak Field Studies Centre, Selangor, A. Nawawi, 1 April, 1987.

The successive proliferations of the conidiogenous cells in **C.cristatum** arise by the extension of the half septum exposed by the schizolytic separation of the conidium. Before conidium secession a partial separation of the layer comprising the septum may already be seen. In optical section a wedge shaped gap appears on each side (Fig. 2,E). The lower half of the septum is apparently continuous with the inner wall of the conidiogenous cell, and as proliferation proceeds that part of the inner wall within the outer wall of the old conidiogenous cell becomes pigmented downwards, and together with the dark and slightly flared edge of the outer wall, a distinct node or band is observed at each proliferation point along the conidiophores. Observations on numerous conidiophores bearing conidia show that the conidia tend to remain at their detachment points, at an inclined angle for some time. Presumably the tear in the wall is not complete. Up to 5 conidia have been observed to remain in situ on a conidiophore. Septa, some with a clear central pore, are formed at irregular intervals in the conidiophores.

The conidia of **C.cristatum** are very characteristic. The truncate, more or less rectangular basal cell is usually darker and shorter, measuring 3.5 – 5 µm long compared to the rest of the conidial cells which measure 8 – 11 µm long. The second cell from the base is rather squarish in outline, with a straight or slightly incurved wall. The rounded apical cell is lighter in colour, thinner-walled and absorbs stain readily. The last two apical transverse septa are usually thicker, often appearing double.

Conidia begin to germinate very soon after their release by the production of a filiform germ-tube through a pore at the base. The fungus can be established readily in pure cultures. On CMA, submerged mycelial growth is dense and dark, with fluffy, ash grey aerial mycelium. Growth is moderate attaining a diam of 45 mm in 60 days at 25 – 28°C. Sporulation is sparse on dry agar but when slivers of colonies are suspended in distilled water, sporulation is abundant on the exposed areas. Conidia formed in cultures are similar to those formed on the leaves.

Conidia apparently belonging to this fungus have been recorded in foam by Tubaki(1965, Pl.2,K) from Papua New Guinea. He ascribed these conidia as belonging to an unidentified species of **Camposporium**, rather similar to those recorded by Ingold(1956), also in foam from Nigeria. We have also recorded conidia of this

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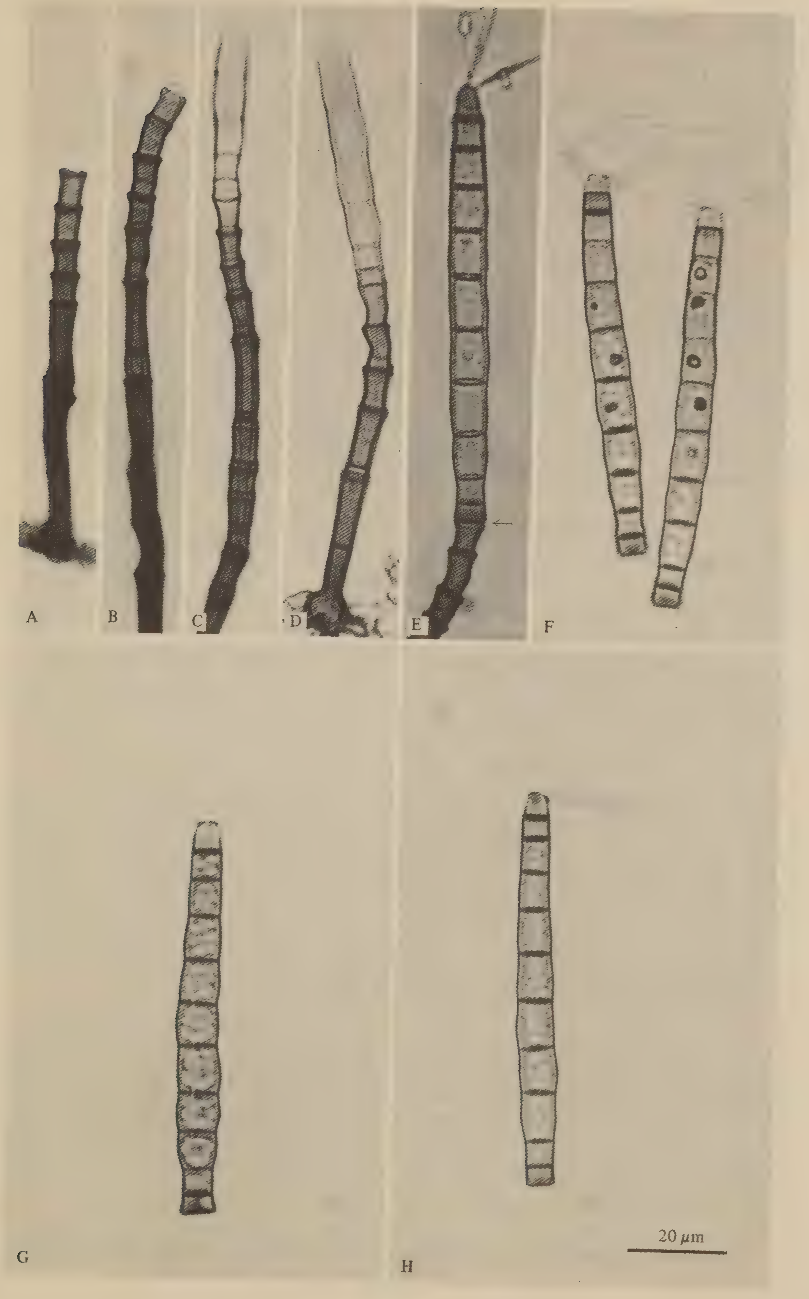
Fig.2. **Camposporidium cristatum.** (A – E) Conidiophores bearing developing conidia; (F – H) conidia from leaves. Arrow indicates point of detachment.


A
B
C
D
E
F
G
H
20 μm

fungus in foam from Malaysian freshwater streams on several occasions.

We have juggled this interesting fungus among species of several established genera of phragmosporous hyphomycetes, e.g. **Camposporium Chaetendophragmia, Pleiochaeta** and **Sporidesmium** but without enough conviction to publish it as novel in any one of them.

Cfr. **Camposporium:** conidia of **Camposporidium cristatum** have characteristics in common with those of **Camposporium,** particularly **C.antennatum** Harkn. the type species, in that the conidia are cylindrical, multiseptate with the apical cell lighter in colour and bearing several hyaline, non-septate filiform appendages. However, their similarities end here, for in **Camposporium** the basal cell is hemisphaerical, typically with a cylindrical pedicel or separating cell. Conidiogenous cells in **Camposporium** are polyblastic, sympodial and denticulate.

Cfr. **Chaetendophragmia:** which is characterised by the percurrent proliferations arising from the penultimate cell of the conidiophore after rhexolytic secession of conidium is different from the present fungus. The truncate, elongo-triangular, multiseptate, coloured conidia have a long terminal non-septate, hyaline appendage plus several lateral appendages downwardly directed arising more or less medially in **C.triangularia** Matsu. and at the base of the attenuated terminal appendage in **C.triseptata** Matsu.

Cfr. **Pleiochaeta:** conidia of **Camposporidium cristatum** also have some characterisitics in common with those of **Pleiochaeta** in that the conidia are cylindrical, multiseptate, truncate at the base with the apical cell bearing several hyaline appendages which are branched in several species. However, in **P.setosa** (Kirchn.) Hughes, the type species, the conidiogenous cells are polyblastic and sympodial and these characters have been considered as diagnostic features for the genus (Ellis,1971).

Cfr. **Sporidesmium:** except for the distinct morphology of their conidia, those of **C.cristatum** show the kind of percurrent proliferation typical of **Sporidesmium,** a large heterogeneous genus with cuneate to obovoid conidia which generally have few septa, to those with long cylindrical, multiseptate conidia, but devoid of any apical appendages. We are reluctant to diversify the genus with the inclusion of the present fungus.

A genus would be established on shaky ground, of course, if it were defined only by an accumulation of small negative observations. In characterizing **Camposporidium**, a unique pattern of conidium morphology and conidiophore proliferation distinguishes the genus from all other phragmosporous hyphomycetes with some otherwise similar characters.

We thank Professor J. Webster, University of Exeter for prepublication editorial vetting of this manuscript.

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MYCOTAXON

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NAMAKWA, A NEW LICHEN GENUS IN THE PARMELIACEAE (ASCOMYCOTINA: PARMELIACEAE)

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Abstract: A new lichen genus, *Namakwa*, is described from South Africa. Closely related to *Xanthoparmelia* (Vain.) Hale, it is characterized by the presence of usnic acid, pseudocyphellae, uniseriate spores and bifusiform conidia.

Namakwa Hale, gen. nov.

Thallus foliaceus, coriaceus firmusque, viridi-flavicans, saxicola, lobis sublinearibus, superne pseudocyphellatus, subtus modice rhizinosus. Pycnidia immersa, conidiis bifusiformibus. Apothecia substipitata, sporis simplicibus, incoloratis.

Type species: *Namakwa exornata* (Zahlbr.) Hale.

Namakwa exornata (Zahlbr.) Hale, comb. nov.

Parmelia conturbata var. *exornata* Zahlbr. *Ann. Crypt. Exot.* 5:252. 1932. Type collection: Steinkopf, Namaqualand, Cape Province, South Africa, *P. G. Mayer* s.n. (W, lectotype; STEU, isolectotype).

Xanthoparmelia exornata (Zahlbr.) Brusse & Knox, *Journ. S. African Bot.* 49:150. 1983.

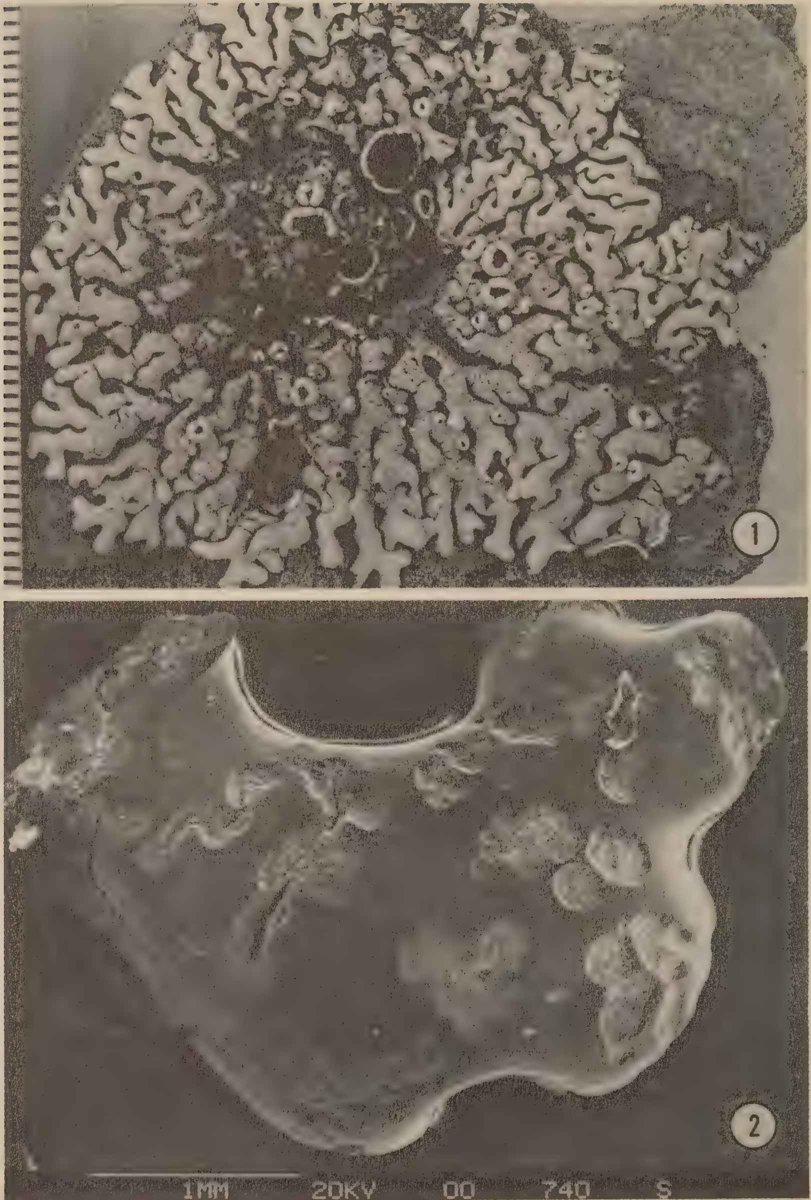
Thallus adnate on rock (Fig. 1), usually collected with the rock substrate (or peeled free of rock if moistened), firm and leathery, 4−10 cm broad, light to dull yellowish green, rarely turning brownish (as in the type specimen); lobes sublinear, 1−3 mm wide, relatively short to elongate, irregularly dichotomously branched, plane to convex, the tips often weakly revolute, black-rimmed, separate to subimbricate; upper surface strongly maculate-pseudocyphellate, shiny, the pseudocyphellae somewhat depressed (Figs. 2−4), orbicular to irregularly elongate, separate, 0.1−0.5 mm long; medulla white; lower surface plane to weakly convoluted, pale brown or darkening, sparsely to moderately rhizinate, the rhizines pale brown to brown, very coarse, simple to sparsely branched, 1−2 mm long. Pycnidia numerous; conidia strongly bifusiform, 0.5 × 4−6 μm. Apothecia common, substipitate, 2−8 mm in diameter, the rim crenate, often inrolled, pseudocyphellate, the disc imperforate; hymenium 40−45 μm high; spores uniseriate, subspherical, 5−6 × 7−9 μm.

Chemistry: Salazinic acid, consalazinic acid, chalybaeizans unknown (±), norstictic acid (±), connorstictic (±), protocetraric acid (±trace), 4 unidentified fatty acids (±). The fatty acids appear to be unique to the genus, falling close to but different from the constipatic acid series.

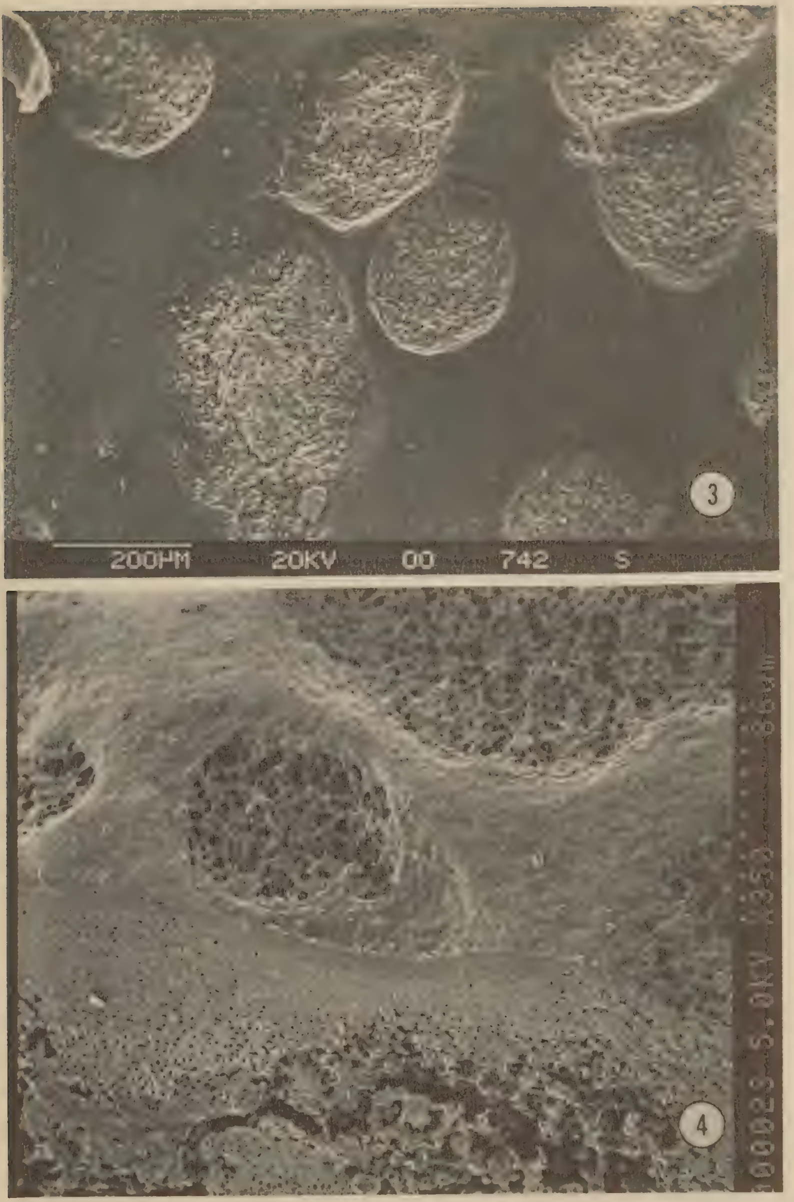
Distribution: South Africa (Cape Province, Transvaal) (Fig. 5).

Representative specimens examined. South Africa. Transvaal: Lejuma Summit, Soutpansberg Mountains, Grid 2329 AB, *Hale* 72090 (US). Cape Province: Seweweekspoort, Grid 3321 AD, *Hale* 73505 (US); Witkransnek Pass, Grid 3125 CA, *Hale* 73214; Swartberg Pass Road, Grid 3322 AC, *Hale* 73230 (US); Prince Albert, Karroo, *Stokoe* s.n. (BOL); 10 km W of Montagu, *Maas Geesteranus* 6724 (LD); 1 km S of Nuwerus, Grid 3118 AB, *Hale* 72247 (US); 8.4 km W of Steinkopf, Grid 2917 BA, *Hale* 73065 (US).

Esslinger (1977) was the first to recognize that the type of *Parmelia conturbata* var. *exornata* is not a brown *Parmelia* but a darkened specimen more appropriately placed in *Xanthoparmelia*. The internal anatomy is close to that of umbilicate *Xanthomaculina* Hale (Hale, 1985). The upper cortex consists of a dense, deeply vaulted layer 100−300 μm thick (Figs. 6, 7). Loose masses of medullary hyphae occupy the peaks and reach the surface in depressed white ecorticate areas which I interpret


1
2
1MM 20KV 00 740 S

Figures 1, 2. *Namakwa exornata*: 1, Thallus (Calitzdorp, South Africa, *Hale* 77519 (scale in mm); 2, SEM of a single lobe (*Hale* 72092).


200µM 20KV 00 742 S
3
4
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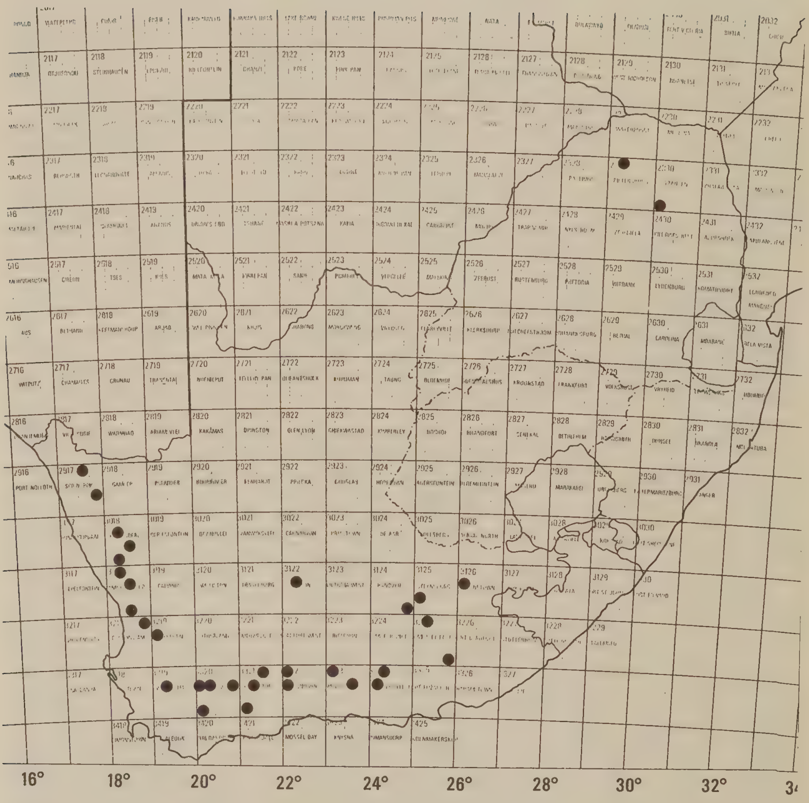
Figures 3, 4. Pseudocyphellae of *Namakwa exornata* with SEM: 3, vertical view (*Hale* 72092); 4, oblique view (*Hale* 72091).


16°
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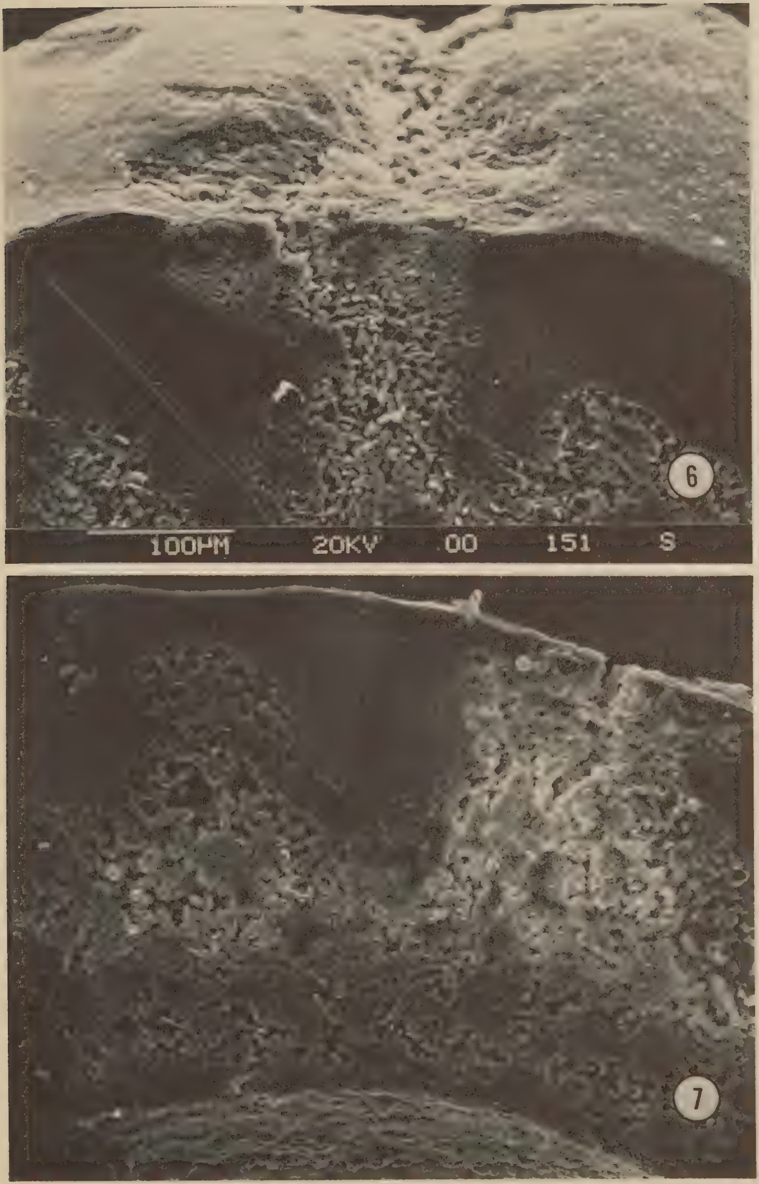
26°
28°
30°
32°

Figure 5. Distribution of *Namakwa exornata* in South Africa.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6
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Figures 6, 7. Vertical cross sections of the thallus of *Namakwa exornata* with SEM: 6, oblique view from top (*Hale* 78505); 7, oblique view from bottom (*Stokoe* s.n.).

as pseudocyphellae. As in related *Xanthomaculina*, lichen, the cortex above the thickened vaulted area is nonepicorticate, but in contrast to *Xanthomaculina*, the layer between vaults is not covered by an epicortex but breaks down as one finds in true pseudocyphellae (Hale, 1981), exposing medullary hyphae. In strongly white-maculate species such as *X. namakwa* Hale (Hale, 1986: fig. 31), the cortex is entirely epicorticate and the maculae, flush with the thallus surface, tend to fuse rather than remain separate.

The conidia are strongly bifusiform, as in most species of *Xanthoparmelia*. The apothecia are typically parmelioid but the spores are uniseriate in the asci, an unusual character in the Parmeliaceae.

This remarkable genus occurs in Namaqualand, in a zone bordering the Great Karoo in Cape Province, and in two isolated localities in Transvaal. It occurs on sandstones and granite, often on the tops of exposed rocks and hard-to-reach ledges where it typically forms large pure colonies. It is easily recognized in the field by the growth habit, color, waxy-yellowish, leathery thallus, and pseudocyphellae easily visible with a hand lens.

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GNOMONIELLA FRAXINI SP. NOV., TELEOMORPH OF THE ASH ANTHRACNOSE FUNGUS AND ITS CONNECTION TO DISCULA FRAXINEA COMB. NOV.

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SUMMARY

A previously undescribed species of Gnomoniella was found on overwintered leaves of green ash (Fraxinus pennsylvanica Marsh.). Cultures derived from ascospores produced an anamorph identical to that in cultures derived from anthracnose-infected green ash leaves. The fungus causing anthracnose of ash has long been known only by its anamorphic state, Gloeosporium aridum Ellis & Holway. Conidia, conidiogenous cells and conidiomata in agar culture and acervuli on leaves were characteristic of the genus Discula. The names Gnomoniella fraxini sp. nov. for the teleomorph and Discula fraxinea (Peck) comb. nov. for the anamorph are proposed.

INTRODUCTION

Anthracnose of ash is caused by two species originally described as Gloeosporium spp.: Gloeosporium fraxineum Peck on Fraxinus pubescens Lam., (=F. pennsylvanica Marsh.) (Peck 1884) and Gloeosporium aridum Ellis & Holway on Fraxinus americana L., separated by size of lesion caused (Ellis & Holway 1887). Von Arx placed the species of Gloeosporium with gnomoniaceous teleomorphs that occur on trees into the genus Discula (Arx 1957). This disposition has been accepted by both Barr (1978) and Sutton (1980). Discula is characterized by acervular epidermal conidiomata and cylindric conidiogenous cells (Asteroma has ampulliform to lageniform conidiogenous cells) (Sutton 1980). Von Arx considered G. aridum, G. fraxineum and G. irregulare that occur on ash (Fraxinus spp.) as well as Gloeosporium species causing anthracnoses of maple (Acer), buckeye

(*Aesculus*), hackberry (*Celtis*), beech (*Fagus*), sycamore (*Platanus*), oak (*Quercus*), and basswood (*Tilia*), in the *Discula* state of *Gnomonia errabunda* (Rob.) Auersw. [=*Apiognomonia errabunda* (Rob.) v. Hohn.] even though the teleomorph of the ash anthracnose fungus had never been described (Arx 1951). Von Arx later argued that this complex of *Gloeosporium* species was morphologically indistinguishable, synonymizing 12 taxa including *G. aridum* under the name *Discula quercina* (West.) Arx (Arx 1957). In his most recent revision of the genus *Gloeosporium*, von Arx referred most of the tree anthracnose fungi to the "*Discula* conidial state of *Gnomonia errabunda* (Rob.) Auersw. [=*Apiognomonia errabunda* (Rob.) v. Hohn.]" (Arx 1970). Sutton showed that the name *D. quercina* (West.) Arx (1957) was incorrect because it was a later homonym of *D. quercina* (Cke.) Sacc. (1884). He proposed the name *Discula umbrinella* (Berk. & Br.) Sutton as the next available combination for this aggregate species (Sutton 1980).

Although the teleomorphs of many of the tree anthracnose fungi have long been known (*Gnomonia leptostyla* [*Sphaeria leptostyla* Fries 1823], *Apiognomonia quercina* [*Gnomonia quercina* Kleb. 1918]), the ash anthracnose fungus has continued to be known as *Gloeosporium aridum* in the plant pathological literature because the teleomorph has not been reported (Ogawa et al. 1977, Sinclair et al. 1987). A biological link to a teleomorph for *G. aridum* has never been demonstrated.

The principal teleomorph genera of tree anthracnose fungi are *Gnomonia* (sensu stricto) and *Apiognomonia*. Both are in the order Diaporthales, family Gnomoniaceae, subfamily Gnomonioideae, tribe Gnomonieae (Barr 1978). The subfamily Gnomonioideae is characterized by non-stromatic single immersed perithecia which occur on overwintered host tissue. Genera within its single tribe, Gnomonieae, are separated by the position and number of septa in the ascospore. In *Gnomoniella* ascospores are nonseptate, in *Gnomonia* ascospores have a single median to nearly median septum, in *Apiognomonia* they are apiosporous and in *Ophiognomonia* they are narrowly clavoid, usually septate and enlarged slightly in the upper third. Within each genus, separation of species is readily accomplished by morphological characters including size and shape of the ascus, ascospores and shape of the ascus apex.

Ash anthracnose, caused by the fungus widely known as

Gloeosporium aridum is a disease of nearly all North American *Fraxinus* spp. *G. aridum* infects mainly leaves but sometimes other plant parts (Coe & Wagener 1949, Snyder & Stack 1983). The annual life cycle is thought to be initiated by rain-splashed conidia produced in acervuli on host tissue infected the previous season. Infected petioles remain on susceptible trees over winter and are ideally placed to be the source of primary inoculum (Ogawa et al. 1977). *G. aridum* can be readily isolated and grown on potato dextrose agar (PDA) (Ogawa et al. 1977, Snyder & Stack 1983). The optimum temperature for conidial germination and growth in culture is 20 to 27 C (Ogawa et al. 1977, Redlin & Stack 1986). Acervuli are produced on infected host tissue from which the fungus is readily isolated. Isolates from all symptom types and plant parts had the same appearance in culture (Snyder & Stack 1983).

METHODS

Collections of anthracnose infected ash leaves were made from sites in North Dakota, South Dakota, and Minnesota from May 1984 through May 1987. The presence of acervuli and/or perithecia was determined by using a dissecting microscope. Collections containing perithecia and a representative selection of those with acervuli were preserved for herbarium specimens.

Cultures were obtained in three ways. Naturally infected leaves with both small (typical of *G. fraxineum*) and large (typical of *G. aridum*) lesions were surface disinfested and small pieces from lesion margins were placed on PDA in petri dishes. Transfers from colony margins were made to new plates of PDA. Resultant cultures were grown at room temperature (20-24 C) ca 30 cm below fluorescent lights (F40 WW + F40 CW) on a 12 h photoperiod for approximately one month. Naturally infected host tissue was also surface disinfested and incubated in a moist chamber for 3-5 days at room temperature to promote sporulation. Masses of conidia exuding from acervuli were transferred with a sterile dissecting needle to PDA and cultures were grown as above.

Single ascospore cultures were derived by crushing mature perithecia in sterile distilled water and sowing the resulting suspensions of ascospores onto water agar in petri dishes. Germinated ascospores were removed after 24 to 48 h using Moore's light location method (Tuite 1969) and placed on PDA. After isolation, cultures were maintained on PDA slants. Cultures were stored at 3 C. Cultures derived in these three ways were used for comparisons of conidiomata and conidia.

Herbarium materials were rehydrated in 1% Aerosol OT wetting agent (Fisher Scientific Company; Fair Lawn, New Jersey) prior to examination of host tissue containing acervuli or perithecia (Whiffen 1946). Photomicroscopy was done using an Olympus model BHS microscope with an Olympus PM-10AD photomicrographic system. Sectioned material and water mounts of asci, ascospores and conidia were photographed on Kodak #2415 Technical Pan film. Water mounts were photographed using differential interference contrast optics (DIC). Measurements were made using an Olympus model CH microscope with an ocular micrometer.

Standard procedures were used for the preparation and examination of specimens for electron microscopy. Specimens were prepared by passing through a graded ethanol series. Critical point drying was accomplished using liquid CO_2 as the transitional fluid. Specimens were mounted on metal stubs and sputter coated with 200 angstroms of gold-palladium and examined with a JEOL JSM-35 scanning electron microscope.

TELEOMORPH - METHODS

Perithecia of many gnomoniaceous fungi are produced naturally in overwintered host tissue or can be induced to form in culture (Klebahn 1918). In the present study, perithecia were examined from the following sources:

Overwintered leaves.

A major emphasis in this study was the examination of overwintered leaves of F. pennsylvanica. Leaflets and petioles were collected from several locations at several times of the year over a three-year period. Overwintered leaves with immature perithecia were incubated to maturity in moist chambers held under 12 h photoperiod at room temperature for 7-20 days.

Overwintered leaflets with perithecia were examined with a dissecting microscope and portions with numerous perithecia were selected, excised, rehydrated and fixed in formalin-acetic acid-alcohol (FAA). Overwintered leaves containing perithecia were embedded in paraffin using standard methods and sectioned at 10 or 15 μm with a rotary microtome. Ribbons were mounted on glass slides and stained with hemalum, safranin O or safranin/fast green (Johansen 1940). Asci and ascospores were measured in water mounts prepared after rehydrating leaflets, removing and squash mounting individual perithecia in 0.25% phloxine in 25% glycerine.

Incubated infected leaves.

Current season leaves with leafspots were collected in May 1985, 1986 and 1987 and stored at 5 C for several months in sealed polyethylene bags to induce the formation of perithecia. Leaves were examined under the dissecting microscope at bimonthly intervals for presence of perithecia.

Herbarium specimens.

Herbarium specimens of Gnomoniella were borrowed from the U.S. National Fungus Collections (BPI) in Beltsville, Maryland. Comparisons were made with perithecia on ash leaf collections.

Biological evidence for an affiliation between the anamorph of the ash anthracnose fungus and any teleomorph has never been reported (Sinclair et al. 1987). Experiments were done to establish such a link following the protocol set out by Kendrick and DiCosmo (1979).

In an initial experiment several different isolates derived from infected host tissue were paired in petri dishes and grown in the light at room temperature until the colony margins overlapped, then stored in the dark at 3 C for 90 days. In another experiment, seven single ascospore isolates were paired (three per plate) in seven combinations on PDA and on water agar (four replicates of each) and incubated at 3 C. In other experiments, aqueous suspensions of ascospores were spread over the surface of water agar in petri dishes and subsequently stored at 3 C for 90 days, as above.

METHODS - ANAMORPH

The anamorph was studied from fresh and dried naturally infected green ash leaf and petiole tissue, from artificially inoculated leaf tissue, from living cultures, and herbarium material. Although sporulation occurred on agar media, the resultant conidiomata, while analogous to acervuli, are morphologically different because by definition acervuli involve host tissue (Sutton 1980). To produce acervuli similar to those occurring on naturally infected leaves, we used an excised leaf disc technique (Redlin & Stack 1985). Leaf discs (either 12 or 18 mm diam.) were cut from healthy leaves and disinfested in 0.25% NaOCl, rinsed twice in sterile distilled water, and placed in corresponding sized wells cut in water agar in petri dishes. Discs were wounded by burning with a heated metal rod. Discs were inoculated with mycelium or spore suspensions and incubated under fluorescent lights for 10-21 days. Acervuli produced on naturally infected host tissue and those formed on leaf discs were compared. Conidia from inoculated leaf tissue were also compared to those from naturally infected leaves.

The anamorphs were compared by examining conidia from the following sources:

Cultures examined.

Discula stage of *Gnomoniella fraxini*; Single ascospore isolate SCR2, ATCC 64469, isolated from type specimen of *G. fraxini* (BPI 71966).
Discula stage of *Gnomoniella fraxini*; Single ascospore isolate SCR3, ATCC 64470, isolated from type specimen of *G. fraxini* (BPI 71966).
Discula sp.; Isolate WB-K, ATCC 64471, isolated from infected *Fraxinus pennsylvanica* tissue.

Specimens examined.

Gloeosporium aridum Ellis & Holway : *Fraxinus americana* Racine, Wisconsin, USA; coll. June 30, 1886 by J. J. Davis, (NY) - holotype.
Gloeosporium fraxineum Peck : *Fraxinus pubescens* Albany, New York, USA, coll. June 1881 by C. H. Peck (NYS) - holotype.
Discula sp.: *Fraxinus pennsylvanica* Grand Forks, North Dakota, USA: coll. June 5, 1986 by S. C. Redlin 86/13.
Discula sp.: *Fraxinus pennsylvanica* Acervuli associated with perithecia of the *Gnomoniella*

fraxini Redlin & Stack holotype on overwintered petioles, coll.: Redlin 85/10 - BPI 71966.

Conidiomata from each of the sources listed above were mounted in Aerosol OT and squashed to liberate conidia. The length and width of conidia were measured at 400X with light microscopy. Photomicrographs were made as described above.

Materials examined were acervuli on dried herbarium specimens and on both naturally infected and artificially inoculated fresh leaves. Conidiomata produced on PDA were compared to these acervuli. All materials were cut in Mellonig's Phosphate buffer with a razor blade and critical point dried prior to SEM examination. In preliminary observation with scanning electron microscopy, the conidia and mucilaginous matrix within conidiomata obscured the conidiogenous cells. A fixation and binding procedure developed for animal tissue (Kelly, Dekker and Bluemink 1975) and adapted to the study of the fungi by Brown & Brotzman (1979) circumvented this problem and was used to study the characteristics of conidiogenous cells and the identification to genus.

RESULTS - TELEOMORPH

Examination of overwintered host tissue.

Perithecia were most frequently observed on leaves overwintered on the ground in damp locations near trees showing disease symptoms. Perithecia were found sparingly in petioles and abundantly in leaflets of overwintered green ash leaves. Several of the collections did not contain perithecia. Trees with anthracnose were evident by the presence of infected overwintered petioles retained on the branches. Perithecia were found on collections from numerous locations in North Dakota, South Dakota and Minnesota in 1985, 1986 and 1987. Although no survey of incidence was made, there was no difficulty in locating sites where overwintered leaves contained perithecia.

Perithecia were black, immersed in the host tissue and thickly scattered in groups (Fig. 1). Elongate necks were frequently erumpent from the lower surface and were rarely observed in the upper surface of leaflets. Perithecia were nonstromatic (Fig. 2,3) and contained nonseptate hyaline ascospores (Fig. 7).

Because the teleomorphs of other Gnomoniaceae such as Gnomonia or Apiognomonia have septate ascospores, particular attention was given to the presence or absence of septa by numerous observations using several techniques. Asci of sequential collections were examined to determine if the the hyaline nonseptate ascospores, characteristic of the genus Gnomoniella, were mature or if they were immature spores of one of the other genera within the tribe Gnomonieae (Fig. 4-7). Ascus walls in later collections of perithecia conformed to the ascospores (Fig. 5). Additional evidence of maturity was that ascospores separated easily from the ascus in water mounts and germinated when placed on agar media. When leaf pieces containing perithecia were incubated in petri dishes nonseptate ascospores were recovered from the dish lids and also from the tips of necks of the incubated perithecia. Septa were never observed.

Neck elongation was associated with perithecial maturity. On overwintered leaflets collected earlier in the season (March-April), perithecia had black-tipped necks and contained no visible asci. On those collected later in the season (May-June), perithecia had nonpigmented elongated necks and mature ascospores. When immature perithecia were incubated under conditions of high humidity, the necks elongated by a nonpigmented extension. The nonpigmented cells formed at the tip of the perithecial neck differed only in lack of pigmentation from the dark brown to black cells which comprise the exterior cells of the neck and body of the perithecium. The earliest observed appearance of perithecia with elongated necks was on December 21, 1986 (Redlin 86/31), possibly the result of mild weather. In

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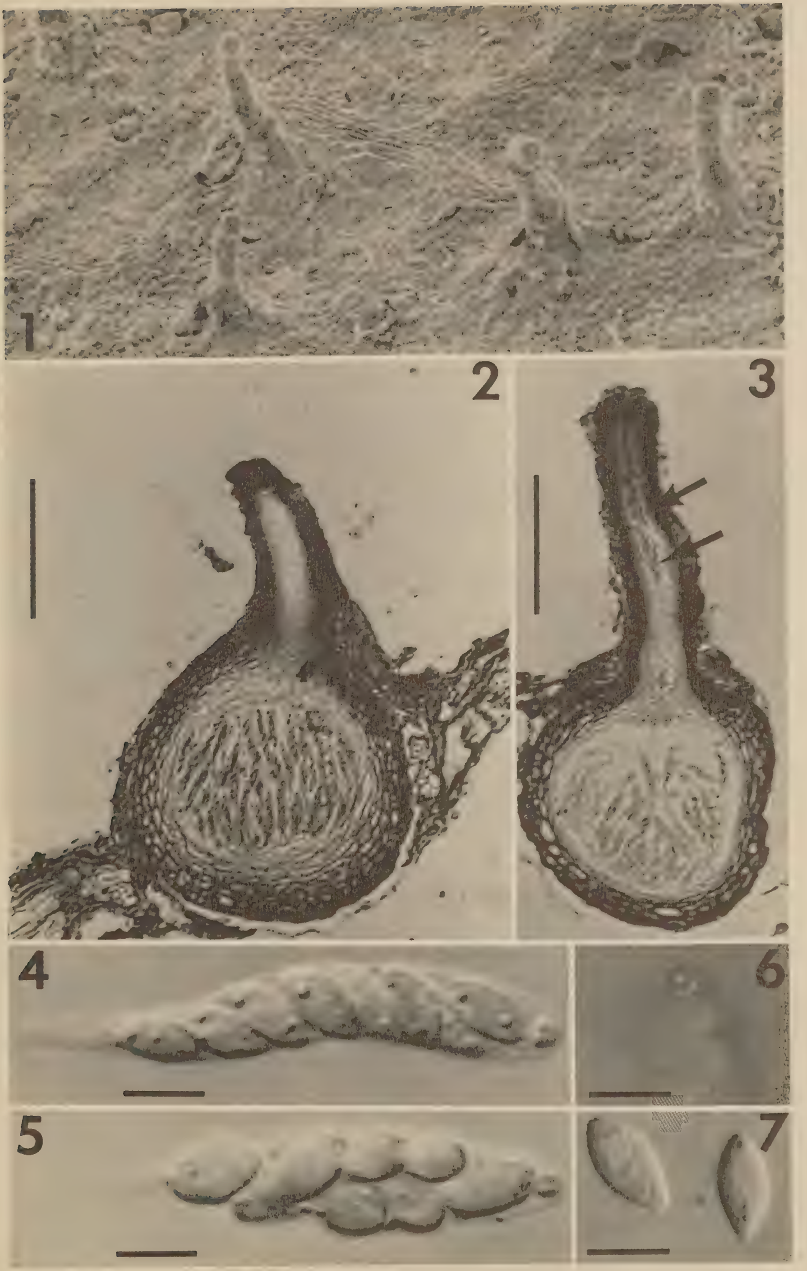
Fig. 1-7. Gnomoniella fraxini. 1. Perithecial necks erumpent through overwintered Fraxinus pennsylvanica leaf tissue. SEM X120. 2. Nearly median longitudinal section of mature perithecium in host tissue showing configuration of asci, sectioned at 15 µm and stained with hemalum. 3. Longitudinal section of mature perithecium, sectioned at 15 µm and stained with Safranin O. Arrows indicate asci in neck. 4. Nearly mature ascus with uniseriate guttulate ascospores. 5. Mature ascus with ascus wall conforming to biseriate ascospores. 4,5. Ascus apices with refractive apical apparatus. 6. Ring-like appearance of ascus apex as viewed from above. 7. Mature ascospores with minute guttulae. Fig. 2,3 - scale indicates 100 µm. Fig. 4-7 - DIC optics; scale indicates 10 µm.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other years, perithecia were usually immature until May. In collections made after July perithecia were empty or contained free, occasionally germinated, ascospores.

Asci within perithecia deliquesced within one h when overwintered leaf tissue containing mature perithecia was immersed in water. Localized individual asci and clumps of asci were occasionally observed in the perithecial necks in longitudinal sections as shown in Figure 3. Masses of ascospores, ascus wall remnants and apical rings of asci were present at the apex of necks of mature perithecia from nature and also when slightly immature perithecia were incubated to maturity.

Paraphyses were not observed in sectioned or squash mounted material at any developmental stage. Asci had the conspicuous refractive apical apparatus characteristic of the order Diaporthales (Fig. 4,5). This appears ring-like when viewed from above (Fig. 6). Rings stained deeply with 1% aniline blue in 50% glycerine (Tu and Kimbrough 1973) or in 1% aqueous nigrosin. Ascospores were initially uniseriate (Fig. 4) maturing to an irregularly biseriate arrangement (Fig. 5). Ascus stalks (Fig. 4,5) became thin, deliquescing at maturity. Ascospores were hyaline, nonseptate, ellipsoidal, obliquely arranged within asci, and contained minute guttulae at maturity (Fig. 7). Ascospores germinated in 24 to 48 h when placed on water agar at room temperature. Single ascospore colonies grew at a rate of 7-9 mm per day on PDA. When centrum suspensions were plated on water agar, spores within intact asci also germinated.

While a number of collections were examined, the description ('descriptio typi') presented here was based on the holotype material Redlin 85/10 deposited at BPI. The measurements presented here are the extreme range and range over two standard deviations about the mean. The sequence of centrum maturation in all of the collections of perithecia fit Luttrell's Diaporthe type of centrum development (Luttrell 1951). The fungus was keyed out to the genus Gnomoniella but did not fit any described species (Barr 1978, Kobayashi 1970, Monod 1983). This material was examined by M. E. Barr of the University of Massachusetts (Amherst) and by M. Monod of the University of Lausanne, Switzerland who both agreed that it was a previously undescribed species of Gnomoniella.

Gnomoniella fraxini Redlin et Stack sp. nov.   Fig. 1-7.

Perithecia in transhiemalibus foliolis et petiolibus, dispersa dense in globis, nigra, paene sphaerica, (114.8-) 117.5-224.7 (-249.2) µm latitudine, (109.2-) 121.7-211.2 (-226.8) µm alta, rostrum paululum arcuatum, fere erumpens ab infimo folii, raro non formatum, (25.2-) 30.8-222.2 (-252) µm longitudine, (25.2-) 30.4-73.8 (-81.2) µm latitudine ad basem, apex perlucidus et rotundatus. Paries 20 µm compositus de 6 ad 7 stratis cellarum. Asci fere cylindrici ellipsoidescentes nullo ordine maturitate, fastigati ad basem (33-) 36.3-59.7 (-64.9) x (6.60) 6.8-12.5 (-20.4) µm. Asci apex aequaliter rotundatus, anulus apicalis eminens, 3 µm. Ascosporae fere uniseriales, biseriatescentes in medio asci, (7.7-) 8.6-12.7 (13.8) x (2.2-) 2.8-5.9 (-6.6) µm, ovoideae vel ellipsoideae, lateribus paululum imparibus, unicellulares, hyalinae, dum parvis guttulis. In transhiemalibus foliolis et petiolibus *Fraxini pennsylvanicae*. Holotypus: Redlin 85/10 (BPI 71966).

Gnomoniella fraxini Redlin & Stack sp. nov.   Fig. 1-7

Perithecia in overwintered leaflets and petioles, thickly scattered in groups, black, nearly spherical, (114.8-) 117.5-224.7 (-249.2) µm diam., (109.2-) 121.7-211.2 (-226.8) µm high, beak slightly curved, usually erumpent hypophyllously, rarely not formed, (25.2-) 30.8-222.2 (-252) µm long, (25.2-) 30.4-73.8 (-81.2) µm wide near base, tip translucent, apex rounded. Perithecial wall 20 µm thick composed of 6 to 7 layers of cells. Asci nearly cylindrical becoming ellipsoid at maturity, tapering at base, (33-) 36.3-59.7 (-64.9) x (6.6-) 6.8-12.5 (-20.4) µm. Ascus apex evenly rounded, apical ring prominent, 3 µm. Ascospores more or less uniseriate becoming irregularly biseriate, (7.7-) 8.6-12.7 (13.8) x (2.2-) 2.8-5.9 (-6.6) µm, ovoid or ellipsoid, ends tapered, slightly inequilateral, unicellular, hyaline, with several small guttules. In overwintered leaflets and petioles of *Fraxinus pennsylvanica* Marsh. North Dakota, South Dakota and Minnesota, U.S.A., North America.

Redlin 85/10 - (Holotype) on overwintered leaflets and petioles collected on May 24, 1985 on the ground beneath *Fraxinus pennsylvanica* Marsh. on the North Dakota State University campus at Fargo, North Dakota. This collection has been deposited in the U.S. National Fungus Collections at Beltsville, Maryland as BPI 71966. Isotypes (Redlin

85/10) are deposited at the Cornell University Plant Pathology Herbarium as CUP 61821, Illinois State Natural History Survey as ILLS 46160 and C.A.B. International Mycological Institute as IMI 320031. Redlin 86/8 (Paratype) is deposited as BPI 71967, CUP 61822, ILLS 46162 and IMI 320032. Redlin 87/4 (Paratype) is deposited as BPI 71968, CUP 61823, ILLS 46161 and IMI 320033. The isotypes and paratypes listed above have also been deposited at the University of Massachusetts (Amherst) - MASS, New York Botanical Garden (Bronx) - NY and New York State Museum (Albany) - NYS under the collector's name and number.

Infected green ash leaves with leaf spots collected on May 29, 1986 and incubated at 5 C for four months resulted in the production of perithecia with mature ascospores. These leaves were accessioned as Redlin 86/10. On these leaves, perithecia were associated with numerous acervuli as shown in Figure 8.

The only species of *Gnomoniella* similar to *G. fraxinii* is *G. vasarii* Monod (Monod 1983), however, the two species differ in several important ways (Table 1).

Table 1. Comparison of *Gnomoniella fraxini* and *G. vasarii*.

Aspect	*Gnomoniella fraxini*	*Gnomoniella vasarii*
Perithecia $\bar{x}$	(subspherical) 171 x 166.4 µm	(spherical) 300 x 300 µm
Asci $\bar{x}$	48 x 9.6 µm	50 x 11 µm
Ascus apex	rounded	flat
Ascospores $\bar{x}$	10.6 x 4.4 µm	13.75 x 3.75 µm
Substrate	overwintered leaflets, petioles of *Fraxinus pennsylvanica* Marsh.	dead leaves, stalks of *Geranium silvaticum* L. (from Monod, 1983)

Gnomoniella fraxini was also compared to the following herbarium specimens from BPI.

Gnomoniella tubaeformis (Fr.) Sacc. on *Alnus* spp.
Buzzard Creek region, Colorado, 24 Jun 1930, R. W. Davidson; Buzzard Creek, Colorado, 24 Jun 1930, R. W. Davidson; Haines, Alaska, 29 Aug 1923, J. P. Anderson; Grand Mesa, Colorado, 12 Jul 1930, R. W. Davidson; Echo Lake, California - 5 Aug 1940, L. Bonar; Berg, Alaska, 17 Aug 1948, C. L. Lefebre.

The average dimensions of Gnomoniella tubaeformis were: Perithecia 347 µm diam, 312 µm high; neck 290 µm long, 96 µm wide near base. Asci 65.5 x 15 µm. Ascospores 16.2 x 7.4 µm, hyaline, broadly ellipsoid, inequilateral.

Gnomonia artospora (Dearn. & House) Dearn. & House (as Gnomonia petiolophila f. fraxini Ell. & Ev.) : Fraxinus nigra, London, Ontario, 3 Apr 1894, J. Dearness (type of G. petiolophila f. fraxini).

The average dimensions of Gnomonia artospora were: Perithecia 325 µm diam. Asci 29 x 6 µm. Ascospores ca. 9 x 1 µm, fusoid with a submedian septum, upper cell slightly wider than lower.

RESULTS - ANAMORPH-TELEOMORPH CONNECTION

Production in culture.

In a preliminary experiment, anamorph isolates from diseased tissue of several symptom types produced perithecia in the zone between colonies after warm incubation and 90 days in cold storage. These gnomoniaceous perithecia were similar to those found in overwintered green ash leaf tissue but the centra were empty and asci never developed. The cultures of paired single ascospore isolates were discontinued after 240 days. No perithecia were formed in any of the pairings of isolates. When mass ascospore suspensions were placed on water agar and held in prolonged 3 C storage, conidiomata and perithecia were produced. Conidiomata produced normal conidia, but as in the initial experiment, the centra of perithecia were devoid of cytoplasm and asci were not observed.

Conidiomata typical of the anamorph were always produced in cultures derived from ascospores. Conidiomata in single ascospore cultures were similar to those in cultures from infected tissue. Acervuli from nature and those resulting from inoculation of leaf discs with single ascospore isolates were also similar. Colony color and morphology as well as mycelial texture were similar for isolates from all sources. Conidia from isolates derived from infected host tissue (Fig. 12) were the same as those from single ascospore cultures (Fig. 13 and 14).

Conidiomata typical of the Discula anamorph were frequently observed to be intimately associated with perithe-

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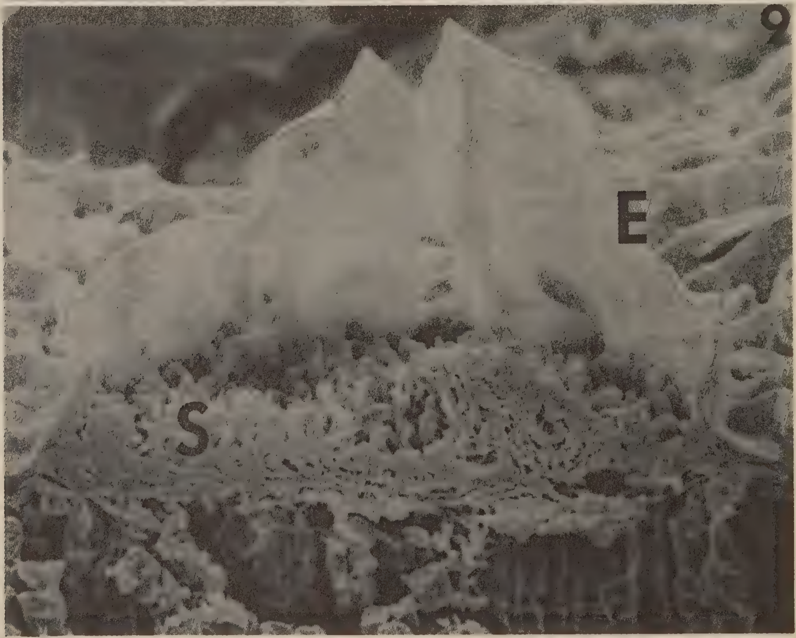
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cia in naturally infected overwintered leaves (Fig. 8), and when newly infected leaves were collected in May and held in cold storage for 3 to 4 months. Both acervuli and perithecia were erumpent from host tissue at maturity.

RESULTS - ANAMORPH

The anamorph of Gnomoniella fraxini has been widely known as Gloeosporium aridum. Von Arx examined material of G. aridum and referred it to Discula. Conidiogenous cells and conidia from naturally infected host tissue, from artificially inoculated and incubated host tissue, from conidiomata grown in culture on PDA plates were compared to the type specimens using light and scanning electron microscopy, and were found to be similar. Conidiomata from culture were different from those on host tissue. The conidiogenous cells in culture were produced in a spherical conidioma whereas those in host tissue were produced in an acervulus (Fig. 9).

Acervuli developing on naturally infected leaves and on artificially inoculated leaf discs were indistinguishable. Acervuli and conidia on inoculated leaf discs were the same for isolates derived from single ascospores and those from diseased tissue. Acervuli and conidia from local collections, such as Redlin 86/13, were the same as those from the type specimens of Gloeosporium fraxineum Peck and Gloeosporium aridum Ellis & Holway.

Acervuli were subepidermal on leaf laminae and intracortical in petioles and were erumpent through the surface when mature. Conidiogenous cells were cylindrical and nonannellated but noticeable swellings or thickenings on the otherwise smooth cells were due to the presence of the hilum, i.e. attachment point of the conidium (Fig. 11). The remnant of the conidial hilum was barely visible at the light microscope level of resolution as a flattened and slightly constricted region on one end of detached conidia

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Fig. 8-9. Host tissue infected by Gnomoniella fraxini. 8. Overwintered leaflet of Fraxinus pennsylvanica with an acervulus (A) on the midvein; necks of immature perithecia. (P) on lower surface of lamina. SEM X180. 9. Longitudinal section of an acervulus showing raised epidermis (E) and conidial stroma (S) above collapsed leaf cells. Mucilaginous matrix and majority of conidia removed in specimen preparation. SEM X880.

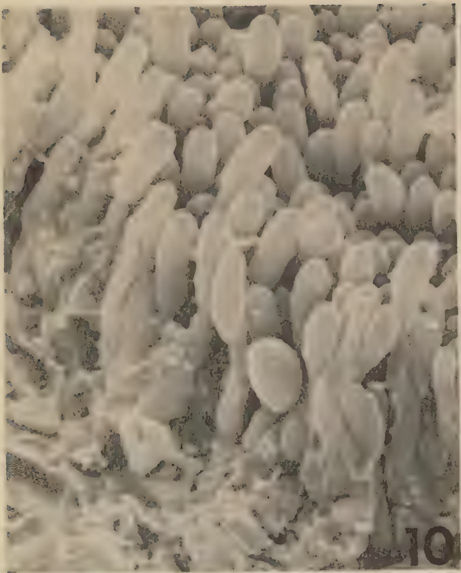
(Fig. 12-14). Conidia were hyaline and nonseptate. Conidia from living cultures had prominent guttulae.

Dimensions of conidia from several specimens were determined (Fig. 15). All of the size ranges overlapped. Although there was a 2.5 µm difference among means, populations of conidia from six sources were not distinguishable (Fig. 15). Size of conidia from culture did not differ from conidia from dried specimens. Several collections were intermediate in size. Due to a slightly skewed distribution of sizes, the ranges were not centered around the means (Fig. 15). The ellipses in Figure 16 show that the 96% confidence limits (± 2 s.d.) of conidial size also overlapped.

Cultures from all sources grown on PDA were similar in colony form, growth and color. Colony color was initially white (Munsell N 9/0) and with age becoming purplish red (Munsell 2.5 R 3/4) when observed under daylight conditions. This color was more prominent from the reverse of the plate. At maturity, conidia oozed from conidiomata in a dull white to pink mucilaginous mass.

Acervuli and conidia of the type specimens of *Gloeosporium aridum* Ellis & Holway and *G. fraxineum* Peck were examined, and found to be the same. Moreover both were identical to the fungus under present study. The only criterion used by Ellis & Holway in 1887 to distinguish *G. aridum* from the previously described (1884) *G. fraxineum* was symptomatology: leaf infection by *G. aridum* caused larger irregular leafspots. Isolates from fresh leaves displaying small spots typical of *G. fraxineum* and from large blotches typical of *G. aridum* were indistinguishable.

Fig. 10-14. *Discula fraxinea*. 10. Palisade of cylindrical phialides in a stroma. SEM X2,400. 11. Conidia on conidiogenous cells with smooth nonannelated surface; hilum indicated at arrows. SEM X12,000. 12. Conidia of isolate WB-K originally isolated directly from infected host tissue. 13. Conidia from a culture derived from a single ascospore isolate SCR2. 14. Conidia from a culture derived from a single ascospore isolate SCR3. Fig. 12-14. Conidia from living cultures grown on PDA and photographed in water mounts using DIC optics; scale indicates 10 µm.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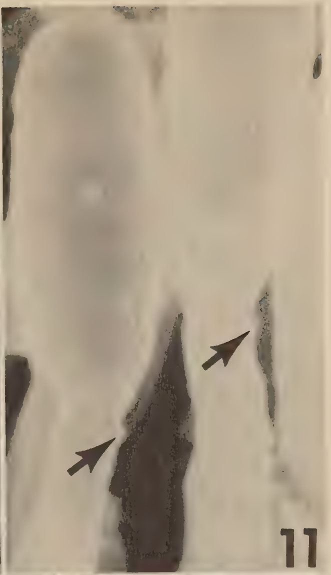
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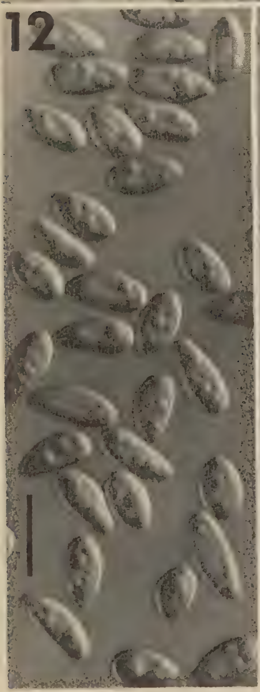
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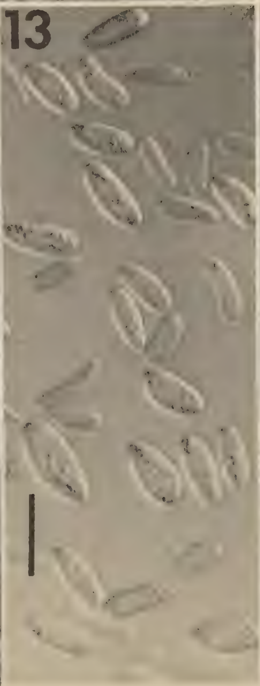
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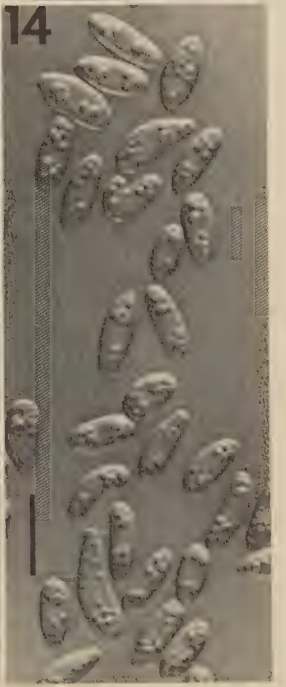
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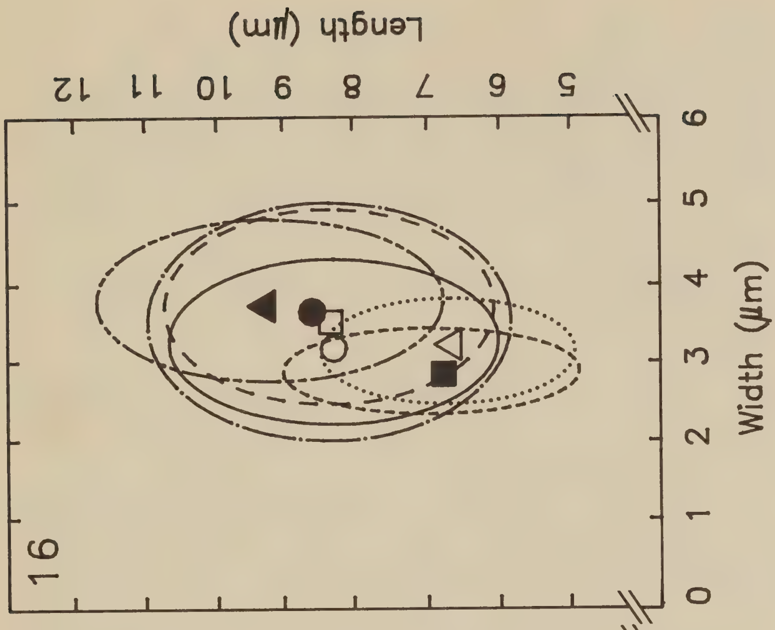
Fig. 15-16. Dimensions of *Discula fraxinea* conidia from six sources. 15. Means and extreme ranges of conidial dimensions (µm) based on measurement of 100 conidia at 400X. 16. Means and confidence limits (±2 standard deviations) of conidial dimensions from same measurements as in Fig. 15. Symbols indicate means for each source. Lines indicate ranges (15) or confidence limits (16). Measurements in 1 through 4 from water mounts of conidia taken from herbarium specimens, those in 5, 6 from water mounts of conidia from living cultures.

1. *Gloeosporium aridum* Ellis & Holway (Type) (NY).
   Mean (○) = 8.3 x 3.2 µm; Range (———————) = 5.6-11.9 X 2.8-5.6 µm.
2. *Discula fraxinea* (Redlin 86/13, Grand Forks, ND).
   Mean (■) = 6.9 x 2.8 µm; Range (----------) = 4.9-9.1 X 2.1-3.5 µm.
3. *Gloeosporium fraxineum* Peck (Type) (NYS).
   Mean (△) = 6.7 x 3.1 µm; Range (················) = 5.6-9.1 X 2.8-4.2 µm.
4. *Discula fraxinea* state of *Gnomoniella fraxini* Redlin & Stack (Type) (BPI 71966).
   Mean (●) = 8.4 x 3.7 µm; Range (— — — — —) = 6.3-11.2 X 2.8-5.6 µm.
5. *Discula fraxinea* state of *Gnomoniella fraxini* Redlin & Stack.
   Single ascospore isolate (SCR2), (ATTC #64469).
   Mean (□) = 8.4 x 3.5 µm; Range (—·——·——) = 5.6-11.9 X 2.1-5.6 µm.
6. *Discula fraxinea* state of *Gnomoniella fraxini* Redlin & Stack.
   Single ascospore isolate (SCR3), (ATCC #64470).
   Mean (▲) = 9.2 x 3.7 µm; Range (--——--——) = 4.9-11.9 X 2.8-4.9 µm.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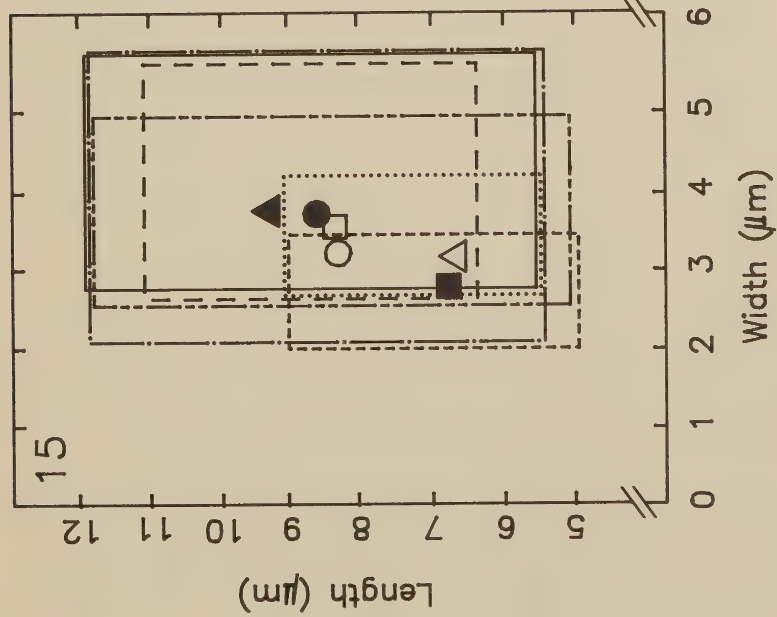
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Section 3, article 11 of the International Code of Botanical Nomenclature states that the basionym for a new combination must be the earliest epithet. The name *Gloeosporium fraxineum* Peck (1884) pre-dates *G. aridum* (1887) and the two species are morphologically indistinguishable. Even though the ash anthracnose fungus is widely known as *G. aridum* E. & H., *G. fraxineum* Peck must be the basionym for the new combination in *Discula* as follows:

Discula fraxinea (Peck) Redlin & Stack comb. nov.
≡ *Gloeosporium fraxineum* Peck, Rep. New York St. Mus. 35:137. 1884
= *Gloeosporium aridum* Ellis & Holway, J. Mycol. 3:21.1887

Acervuli erumpent when mature, on leaf laminae subepidermal, rounded, 33-262 µm, on ribs and petioles subepidermal to intracortical, cupulate, elliptical, 111-345 x 67-256 µm; conidiogenous cells in a single layer, phialidic, cylindric, nonannelated, smooth, with slight swellings due to the conidial hilum; conidia hyaline, ellipsoid, nonseptate, 4.9-11.9 µm x 2.1-5.6 µm, in life with prominent guttulae, embedded in a mucilaginous matrix, dull white to pinkish in mass.

In culture on PDA at 20-24 C, aerial mycelium slightly flocculent, white to purplish red, showing conspicuous concentric zones of alternating dense and sparse aerial mycelium when grown under alternating light and dark conditions; purplish-red pigment usually produced in the agar within the colony margin, growth rate of freshly isolated cultures 7-9 mm per day, colony morphology and growth on malt agar similar to that on PDA but with reduced pigmentation.

Conidiomata abundant after 10 days in newly isolated cultures, rounded, 100-900 µm, soon producing slimy masses of conidia, initially dull white becoming pink; conidia indistinguishable from those from acervuli. Repeated mycelial transfer resulted in reduced sporulation, often correlated with slower or erratic mycelial growth.

Lesions on infected host leaves range from small discrete necrotic spots (1-3 mm) surrounded by a purplish margin, often associated with insect feeding injuries, to large rounded to irregular necrotic blotches (5-50 mm); lesions often spreading to affect entire leaflet.

DISCUSSION

The Gnomoniaceae are known to exhibit perithecial neck elongation via meristematic growth (Wehmeyer 1975). Elongation of the necks by nonpigmented cells during perithecial maturation was observed in *Gnomoniella fraxini*. In sections of mature perithecia, asci were observed in the perithecial necks, probably migrating up the neck prior to discharging their ascospores at the tip. Ascospore discharge in this way has been reported. In *Gnomonia rubi* (Rehm) Winter in Rabenh., asci mature, become detached from the subhymenium, migrate up the neck and then ascospores are discharged (Dowson 1925). Asci becoming free by deliquescence of bases is a characteristic of the Gnomoniaceae (Barr 1978). Ingold (1971) also found this mechanism in a species of *Ceratostomella*.

Acervuli of the anamorph of *G. fraxini* resemble the *Discula umbrinella* conidioma figured by Sutton (1980 Fig. 303). Monod described the anamorphs of *Apiognomonia veneta* (1983, Fig. 8:5) and distinguished *Gloeosporidium* Hohn. from *Discula* Sacc. (sensu stricto) based on the position of the conidiogenous cells in relation to the host tissue. In our observations, the position of acervuli may be influenced by the host tissue in which they occur, being shallow (subepidermal) in thin tissue (leaf laminae) and deeply cupulate (intracortical) in thicker tissue such as petiole cortex. We therefore accept the broader concept of *Discula* stated by Von Arx and followed by Sutton (1980).

A protocol for ordering the evidence of affiliation between anamorph and teleomorph was proposed by Weresub and Pirozynski (Kendrick & DiCosmo 1979). Factors considered include degree of documentation and casual, circumstantial or experimental evidence of connection. This procedure was followed to demonstrate the connection of the two states in both cultural studies and examination of host tissue. The criterion for the demonstration of a connection was fulfilled here by producing one state (anamorph) in culture from single spore isolates of the other (teleomorph) as well as the observation of intimate association of the two morphs. Sterile perithecia formed in mated cultures derived from the anamorph. Regular cohabitation of the anamorph and teleomorph or their morphological similarity is circumstantial evidence of the connection. Immature perithecia on overwintered petioles somewhat resemble immature acervuli because neither are erumpent and perithecial necks are not developed.

This is the first known species of Gnomoniella with a Discula anamorph. Other species of Gnomoniella are known to have anamorphs in Cylindrosporella, Monostichella (Monod 1983) or Asteroma (Sutton 1980); however, anamorphs have not been reported for several Gnomoniella species (Barr 1979, Monod 1983). Other species of Discula connect to the gnomoniaceous genus Apiognomonia (Sutton 1980). Many of the gnomoniaceous species have been studied only from herbarium specimens, so that information on the production of anamorph structures either in culture or on living hosts is lacking.

Because the species in the Gnomoniaceae are morphologically distinguishable (Barr 1978), the contention of von Arx (1957) that the separation of the species causing tree anthracnoses is strictly by host is incorrect and his grouping of these fungi into an aggregate species is inappropriate. Barr and others have rejected von Arx's concept of an aggregate species, Gnomonia errabunda (Rob.) Auersw. [=Apiognomonia errabunda (Rob.) v. Hohn.], for the teleomorphs of the tree anthracnose fungi and therefore implicitly reject the synonomy of their anamorphs (Barr 1978, Monod 1983, Neely & Himelick 1967). Our discovery that the teleomorph of Discula fraxinea is in a different genus (Gnomoniella) from the other anthracnose fungi also supports the rejection of von Arx's aggregate species concept.

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STUDY ON THE PHYSIOLOGICAL CHARACTERISTICS OF THE GENUS *PHYTOPHTHORA*[1]

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ABSTRACT

The physiological characteristics of 104 isolates representing 49 species of *Phytophthora* available from the American Type Culture Collection were studied under uniform conditions, including growth rates, maximum and minimum growth temperatures, ability to utilize nitrate nitrogen and starch, sensitivity to malachite green and hymexazol, pigment production and growth on apple fruit. The significance of physiological criteria in *Phytophthora* taxonomy is reviewed and discussed.

INTRODUCTION

Phytophthora was set up as a new genus in Phycomycetes by de Bary (1876) with the description of *Phytophthora infestans*, the fungus causing potato late blight in Ireland. Although its biology has been extensively reviewed over the years, species differentiation within this genus is still far from satisfactory (Ho & Jong, 1987). The wide host range and diverse geographical distribution made its study complex while a shortage of cultures (of all species) available at a single lab prevented investigators from surveying the whole genus under standard conditions. Traditionally, morphological characteristics serve as the basis for taxonomy though these characters are few and variable. Many interspecific similarities blur the screen of taxonomy and produce controversies among investigators (Erwin, 1983). It is obvious that ideally taxonomy of *Phytophthora* should be based on the physiology, pathology, serology, cytology, biochemistry, and genetics rather than morphology alone.

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Although physiological characters have been used in most keys (Leonian, 1934; Tucker, 1931; Waterhouse, 1963; Ho, 1981), the physiological studies on Phytophthora are incomplete (Cameron & Milbrath, 1965; Hohl, 1975; Leonian, 1925; and Roncadori, 1965). The research described here concerns the physiological characteristics of 104 isolates representing 49 species of Phytophthora from the American Type Culture Collection, studied under the same laboratory conditions.

MATERIALS AND METHODS

1. Isolates used in the Study:

Type or authentic cultures, A1 and A2 mating types and/or representative isolates were chosen (Table 1).

2. Culture Maintenance and Media:

Isolates were maintained on clarified V8 agar (CV8) slants at 5 C and 15 C. Some cultures which showed signs of contamination by bacteria or other fungi were purified on selective agar medium (Ribeiro, 1978) before being put into use or transferred to storage. The media used in the study were: corn meal (CM), CV8, malt extract, hymexazol, malachite green, pigment production, nitrate, and starch utilization agar media. All media were autoclaved at 15 lbs. per sq. inch at 121 C for 15 minutes. Unless otherwise specified, pre-sterilized disposable plastic Petri dishes (90mm) were used in all culture experiments. Each dish was filled with about 20 ml agar medium.

Corn Meal Agar Medium (CM): 17 g Difco corn meal agar was dissolved in 1000 ml distilled water.

Malt Extract Agar Medium: 45 g Difco malt extract and 18 g Difco Bacto agar were dissolved in 1000 ml distilled water.

Clarified V8 Juice Medium (CV8): 2.5 g of CaCO3 was added to 200 ml V8 juice (Campbell Soup Company). The above CaCO3-V8 juice mixture was centrifuged at 1000 RCF for 15 minutes. 200 ml supernatant was diluted to 1000 ml with distilled water and 15 g agar was added.

Hymexazol Agar Medium (HMI): Stock solution (25 mg/ml) was made from 2.5 g hymexazol dissolved in 100 ml distilled water. HMI agar medium was prepared by adding 1 ml stock solution to 500 ml CM agar medium giving a final HMI concentration at 50 μg ml.

Malachite Green Medium: Malachite green stock solution (62.5 mg/ml) was prepared by dissolving 6.25 g malachite green in 100 ml distilled water. 1 ml of stock solution was added to 500 ml CM agar medium to give a concentration of 125 μg/ml of malachite green.

Nitrate Agar Medium: Nitrate agar medium used in this study was a modification of Ribeiro's medium (1978) with L-asparagine omitted. Pigment Production Medium was prepared as described by Timmer *et.* *al.* (1970). Starch utilization medium was prepared as described by Ho and Foster (1972).

3. Growth Rates and Chemical Sensitivities:

Each isolate was allowed to grow first on CM agar plates. Small mycelial agar plugs were made by a No. 5 cork borer. Each plate was inoculated with an agar plug in the center and incubated at 20 C. Growth rates on CM, CV8, malt, and nitrate agar media were measured along two perpendicular lines on the bottom of the Petri dish through the center of the colony. About three days after inoculation, colony diameter (d1) was measured and a second measurement (d2) was made 2-3 days later. Daily growth rate was calculated from the formula:

$$\text{Growth rate (mm/day)} = \frac{d2 - d1}{\text{Number of days between d1 and d2}}$$

Three replicates were made for each test. The whole experiment was conducted two or three times. The final growth rate was the average of all these replicates.

Data on HMI and malachite green were presented as percentages of the growth rates on CM medium which was used as a "control".

Colony patterns on V8, PDA and malt extract agar medium were also noted and classified as follows:

0: No growth
1: Radiate (Uniformly radiate hyphae)
2: Chrysanthemum (narrow petaloid sectors)
3: Rose or camellia (broad, rounded petaloid sectors)
4: Stellate (intermediate between radiate and chrysanthemum)
5: Uniform (without any obvious pattern)

4. Minimal and Maximal Temperatures for Growth:

Each isolate was tested on CM medium at a minimum of 5 C and a maximum of 35 C. If an isolate failed to grow at 5 C, it would be tested at 10 C and if needed at 15 C; if it failed to grow at 35 C, it would be tested at 30 C and if needed, at 25 C. The tests were carried out in incubator chambers while water baths were employed for 30 C and 35 C. Both plates and slants were used in the temperature study. Three replicates were used for each isolate.

The minimal and maximal growth temperatures were ranked as following: 1 = under 5 C, 2 = 5-10 C, 3 = 10-15 C, 4 =

25-30 C, 5 = 30-35 C, 6 = over 35 C.

5. Starch Utilization:

The colony diameter was recorded before it reached the edge of the plate. Starch hydrolysis was determined by flooding the agar plates with iodine solution (1 g iodine, 2 g potassium iodine, 300 ml distilled water). The nonhydrolysed starch formed a deep blue complex with the iodine, whereas the hydrolysed starch was not stained. A clear hydrolysed zone appeared within the fungal colony if the isolate utilized starch as the carbon source to sustain its mycelial growth. The fungal capability to hydrolyse starch on agar medium was represented by "Starch Hydrolysis Index" (S.H.I.) defined by the following formula: S.H.I. = diameter of clear zone(d)/diameter of fungal colony(D) (Ho & Foster, 1972).

6. Pigment Production:

The pigment production experiment was carried out on agar slants. About 5 ml pigment production medium was poured into each test tube (150 x 15 mm), and then autoclaved. Every tube was inoculated with one plug and three replicates were made for each isolate. The slants were incubated at 20 C for 3-4 weeks. The degree of brown pigmentation produced by the isolate was checked by comparing the slant with an uninoculated slant on a white paper under a fluorescent lamp. The degree of pigmentation was defined as follows:

0 - none, 1 - slight, 2 - moderate, 3 - abundant.

7. Apple Inoculation:

Fresh, healthy looking McIntosh apple fruits were first washed with detergent - chloroform mixture, then surface sterilized by wiping with a piece of cheesecloth soaked with 95% alcohol. Inoculation was made by placing mycelial cultures about two weeks old in small slits 3-4 mm deep. The wounds were covered with parafilm and the whole apple was put into a plastic sandwich bag, sealed and incubated at 20 C. Four wounds were made on each apple, three of them inoculated while the other one serving as the control. Results were recorded in two weeks. The virulence or pathogenicity of an isolate to wounded apple fruit was recorded as follows:

0:	No infection	(None)
1:	Lesion diameter below 20 mm	(Slight)
2:	Lesion diameter 20-50 mm	(Moderate)
3:	Lesion diameter over 50 mm	(Serious)

RESULTS

The results of all experiments are summarized in Table 2.

DISCUSSION

Present study is the first attempt in *Phytophthora* research to compare the physiological characteristics of many isolates of all *Phytophthora* species under the same condition. It has confirmed the intraspecific and interspecific variabilities reported by previous workers and provided more new information.

1. Growth Rate on V8 and CM:

Growth rates varied among isolates of one species even under the same condition. However, slow growth seemed to be characteristic of *P. clandestina*, *P. fragariae*, *P. ilicis*, *P. lateralis*, *P. porri*, *P. primulae*, *P. syringae*, and most of the marine forms of *Phytophthora*, including *P. bahamensis*, *P. epistomium*, *P. operculata*, *P. spinosa*, and *P. vesicula*.

2. Growth Temperatures:

Almost all keys (Tucker, 1931; Waterhouse, 1963; Ho, 1981) used growth at minimum and maximum temperatures as a useful taxonomic criterion which is valuable at the species level. Most isolates in present study had maximum growth temperatures around 30-35 C. *P. drechsleri* (ATCC 46724), *P. melonis*, *P. nicotianae* and *P. insolita* could grow at a temperature slightly higher than 35 C while some other isolates e.q., *P. citricola* (ATCC 52855, ATCC 52230), *P. fragariae*, *P. hibernalis*, *P. ilicis*, *P. lateralis*. *P. phaseoli*, *P. porri*, *P. syringae*, *P. pseudotsugae*, *P. humicola* and *P. clandestina* had lower maximum growth temperatures 25-30 C.

Most isolates had minimum growth temperatures around 5 -10 C or below 5 C. Several species had higher minimum growth temperatures around 10-15 C. These included: *P. botryosa* (ATCC 26481), *P. heveae*, *P. meadii* and *P. iranica*.

3. Growth on Malt Extract Agar Medium:

Tucker (1931) was probably the one who did the most work on the growth rate on malt extract agar. He separated *P. phaseoli* and *P. infestans* which failed to grow on malt agar medium from the others which showed abundant to fair growth on the same medium.

In our study, most isolates had similar growth rates (2 - 10 mm/day) on this medium. *P. fragariae*, *P. hibernalis*,

P. ilicis, P. infestans (ATCC 16980), P. phaseoli, P. clandestina, P. bahamensis, and P. epistomium showed either no or very limited growth on malt agar.

4. Utilization of Nitrate Nitrogen:

Although Phytophthora spp. generally prefer organic nitrogen sources, a few species appear to have an absolute requirement for them. Among these are strains of P. infestans, P. fragariae, and P. bahamensis (Hohl, 1983). In our study, growth rate on nitrate nitrogen medium was generally slower than on the other regular growth medium. However, most of them still could grow well while the following isolates failed to grow or showed very slight growth: P. fragariae, P. infestans (ATCC 32835, 16980), P. phaseoli, P. bahamensis (ATCC 28297), and P. epistomium.

5. Starch Utilization:

In present study, the following isolates could not use starch as a carbon source for growth: P. cambivora, P. capsici (ATCC 46012), P. cinnamomi, P. fragariae, P. infestans, P. ilicis, P. hibernalis, P. heveae, P. katsurae, P. lateralis, P. megakarya, P. spinosa, P. melonis, P. palmivora (ATCC 26201), P. phaseoli, P. porri (ATCC 52729), P. primulae, P. quininea, P. richardiae, P. syringae (ATCC 16709), P. insolita, P. humicola, P. bahamensis, P. epistomium and P. operculata. Most isolates had a S.H.I. (Starch Hydrolysis Index) ranging from 20-90%. Similarly, Ho and Foster (1972) found that P. cambivora, P. fragariae and P. infestans could not grow on starch agar medium. It is possible that isolates of the same species may vary in their ability to hydrolyse starch.

6. Sensitivity to Malachite Green:

Leonian (1930) first described the differential inhibition of growth of Phytophthora species by malachite green and used this information to construct a key for species identification, a practice followed by Frezzi (1950) and Leonian (1934). Shepherd and Pratt (1973) and Shepherd (1976) employed malachite green in the assay of Phytophthora isolates in Australia.

In present study, growth rates of P. capsici (except ATCC 52776), P. botryosa (ATCC 58105, 58221), P. citricola (ATCC 28192), P. erythroseptica (ATCC 16699), P. katsurae (ATCC 58598), P. primulae and P. spinosa var. spinosa were stimulated by malachite green. Phytophthora fragariae, P. hibernalis (ATCC 56353, 32995), P. ilicis, P. infestans (ATCC 16980), P. lateralis, P. megakarya (ATCC 42100), P. megasperma (ATCC 44390), P. phaseoli, P. porri, P. vignae, P. clandestina, P. bahamensis, and P. epistomium were inhibited on this medium.

7. Sensitivity to Hymexazol:

Tay et al. (1983) showed that species of Waterhouse's group I - III and V showed reduced growth on a HMI medium whereas the growth of isolates from group VI was enhanced. Papavizas et al. (1981) found that the sporangial development of *P. capsici* was inhibited on a medium containing Hymexazol. However, intraspecific variation in sensitivity to HMI existed in *P. capsici*. Hansen et al. (1979) found that the addition of HMI inhibited growth of *P. lateralis* and *P. cactorum*. Shen and Tsao (1983) tested the sensitivity of *P. infestans* to HMI and found the mycelial growth of all five isolates was slightly inhibited on selective medium with the addition of HMI. Tsao and Guy (1977) indicated that some strains of *P. palmivora* were more sensitive to HMI than the others in the same species.

In present study, HMI had stimulative effect on the growth of *P. capsici* (ATCC 52776), *P. katsurae* (ATCC 58598), and *P. spinosa* var. *spinosa*. On the other hand, *P. fragariae*, *P. ilicis*, *P. phaseoli*, *P. porri*, *P. clandestina*, *P. bahamensis* and *P. batemanensis* grew poorly on this medium. *Phytophthora fragariae* showed a slight growth on frozen lima bean agar and frozen green been agar supplemented with 100 μg/ml HMI. (George and Milholland, 1986). The discrepancy may be due to the different basal media used.

8. Pigment Production:

Galindo and Zentmyer (1967) first reported production of an extracellular pigment in peptone beef extract agar by *P. drechsleri*. They used it to differentiate variants within progeny of crosses of A1 and A2 isolates of *P. drechsleri*. Since the pigment produced on peptone beef extract agar was not intense enough to differentiate various isolates, Timmer et al. (1970) tried several reagents and finally decided that casein hydrolysate and tyrosine agar in the absence of glucose facilitated the production of pigment.

Shepherd (1976) studied pigment production of 138 isolates of 12 Australian species on a casein hydrolysate-tyrosine medium. *Phytophthora drechsleri* showed the darkest pigment whereas no pigment was produced by *P. cinnamomi*. *Phytophthora nicotianae* A1 compatibility type isolates produced approximately double the pigment of A2 type isolates. Although pigment production was said to be a poor taxonomic criterion, the degree of pigment production by unknown isolates might help confirmation following species identification by morphological criteria, or as a preliminary screening. Pigment production was of value in specific cases with regard to intraspecific taxonomy, e.g., a significant difference was shown in pigment production between groups of northern and southern ecotype isolates of *P. drechsleri* in Australia.

In present study, most isolates produced brown pigment on tyrosine-casein hydrolysate agar, ranging from slight to deep dark brown. A few isolates e.g., *P. aquatica*, *P. infestans* (ATCC 32835) had a reddish or honey color at the beginning but eventually turned into brown. Absence of pigment production was observed in *P. areceae*, *P. botryosa*, *P. capsici*, (except ATCC 56600), *P. cinnamomi*, *P. citricola*, *P. hibernalis*, *P. ilicis*, *P. meadii*, *P. melonis*, *P. mexicana*, *P. phaseoli*, *P. quininea*, *P. richardiae*, *P. vignae*, *P. pseudotsugae*, and *P. vesicula*.

9. Apple Inoculation:

Almost all the isolates could infect apple fruit, resulting in brown lesion around the site of inoculation. Species that produce no or very slight lesion included *P. fragariae*, *P. infestans* (ATCC 32835, 16980), *P. meadii*, *P. megasperma* (except ATCC 38828), *P. porri*, *P. iranica*, *P. bahamensis* and *P. spinosa*.

Phytophthora pseudotsugae (Hamm & Hansen, 1983), *P. colocasiae* and *P. richardiae* (Tucker, 1931) believed to be non-pathogenic to wounded apple, caused slight to moderate lesions on apples in present research. While *Phytophthora* lesions on apple fruit were firm, lesions caused by some aquatic isolates e.g., *P. gonapodyides* seemed to be quite soft and watery, similar to those caused by *Pythium* spp..

Thus in general, physiological characters taken singly or considered together cannot define any *Phytophthora* species but they are still valuable aids in *Phytophthora* taxonomy to supplement classical morphological criteria. For instance, *P. fragariae* can be readily distinguished from other *Phytophthora* species producing non-papillate, internally proliferating sporangia by its distinctly slower growth rate and its inability to grow on nitrate nitrogen agar or malt extract agar medium. *Phytophthora phaseoli*, though similar morphologically to *P. infestans* (Waterhouse, 1963) can be separated by its slower growth rate. Although *Phytophthora* species often exhibited broad intraspecific variation in their physiological characters, conspicuous differences displayed by a certain isolate often suggest the need for critical re-evaluation of its taxonomic position. Thus, prompted by Hohl's observation (1975) that a strain of "*P. infestans*" differed from other strains of this species in growing well on a medium containing nitrate as the nitrogen source, Galindo and Hohl (1985) conducted further studies on the nutritional, biochemical, morphology and host range of this isolate and re-named it as *P. mirabilis*. Similarly, while one isolate of *P. palmivora* (ATCC 26200) grew well on starch agar medium as reported by Ho and Foster (1972), the other isolate (ATCC 26201) was similar to *P. megakarya* in failing to hydrolyse starch. A close morphological study of ATCC 26201 (Ho, unpublished) shows that it produces sporangia with narrow, nonoccluded pedicel of intermediate length, characteristic of P. megakarya (Brasier and Griffin 1979).

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Table 1. Isolates of *Phytophthora* Used in the Study

Name	Mating Type	ATCC No.	Host Plant/Substrate	Origin
P. aquatica		62088(T)	Water	United Kingdom
P. areceae		46716	*Areca catechu*	India
P. bahamensis		28296(T)	Decaying *Rhizophora* maple leaf	Bahamas
		28297	Decaying leaf	Bahamas
P. batemanensis		56965(T)	Fallen *Avicennia marina* leaf	Australia
P. boehmeriae		52856	Cotton	China
		46717	Soil	New Guinea
		60238(T)	*Boehmeria nivea*	Taiwan
P. botryosa	A2	58105	*Hevea brasiliensis*	Malaysia
	A2	52221	Rubber tree	Malaysia
	A2	26481(T)	*Hevea brasiliensis*	Malaysia
	A2	62533	*Hevea brasiliensis*	Malaysia
P. cactorum		52859	*Hevea* sp.	China
		62089	*Pyrus communis*	Canada
P. cambivora	A1	38811	Apple	Japan
	A2	46719	Noble fir	USA
P. capsici	A1	56600	*Capsicum annum*	China

Table 1. (continued)

Name	Mating Type	ATCC No.	Host Plant/Substrate	Origin
P. capsici	A2	15399	Pepper	Unknown
	A1	46012	Cacao	Mexico
	A2	52776	Macadamia	Hawaii, USA
P. cinnamomi	A2	32992	Avocado	USA
	A1	32993	Camellia	USA
	A2	46671(T)	Cinnamomum bermanni	Sumatra
P. citricola		52855	Citrus	China
		28192	Soil	Australia
		52230	Avocado	Mexico
		46298	Fraser fir	USA
P. citrophthora	N	56195	Hevea sp.	China
	N	13613	Citrus	USA
	N	56599	Citrus	China
P. clandestina		60438(T)	Clover	Australia
P. colocasiae	A2	56193	Taro	China
	A1	52233	Colocasia esculenta	India
P. cryptogea	A1	56962(T)	Lycopersicon esculentum & Petunia	Ireland
	A1	46721	Lycopersicon	Ireland
	A2	52404	Begoniae-Elatior	Germany
P. drechsleri	A2	46724	Potato	USA
	A2	26756	Carthamus tinctorius	Unknown
	A1	15428	Dalmatian insect flower	Unknown
P. epistomium		28293(T)	Decaying leaf	USA
P. erythroseptica		58104(T)	Solanum tuberosum	Ireland
		16699	Solanum tuberosum	India
P. fragariae		58229	Strawberry	United Kingdom
		11374	Strawberry	USA
		13974	Strawberry	USA
		13977	Strawberry	USA
P. gonapodyides		46726	Vegetable debris	United Kingdom
		60351	Unknown	Unknown
P. heveae		16700	Hevea sp.	Malaysia
		58815	Hevea brasiliensis	Malaysia
P. hibernalis		56353	Citrus sinensis	Australia
		32995	Navel orange	California
		60352	Citrus sinensis	Unknown

Table 1. (continued)

Name	Mating Type	ATCC No.	Host Plant/Substrate	Origin
P. humicola		52179(T)	Soil	Taiwan
P. ilicis		56615	Holly	Canada
P. infestans	A2	32835	Potato	Mexico
	A1	16980	Tomato	USA
	A1	48718	*Lycopersicon esculentum*	USA
	A2	60180	Potato	Switzerland
P. insolita		38789	Soil	Taiwan
P. iranica		60237	*Solanum melongena*	Iran
P. katsurae		58598	Coconut	USA
		36818	Soil	Taiwan
P. lateralis		58599	Port Oxford cedar	USA
		58816(T)	*Chamaecyparis lawsoniana*	USA
P. meadii	A2	58103	*Hevea brasiliensis*	India
	A2	52236	Unknown	Unknown
P. megakarya	A2	42100(T)	Cocoa	Cameroon
	A1	46728	Cocoa	Nigeria
P. megasperma	A1	38828	Alfalfa	Canada
		58969	Alfalfa	Canada
		48604	Arrowleaf clover	USA
		58817(T)	*Althea rosea*	USA
		16706	Soybean	USA
		44390	Alfalfa	USA
P. melonis	A2	58427	Cucumber	Japan
	A1	52854(T)	Cucumber	Japan
P. mexicana		46731	Unknown	Unknown
P. nicotianae	A2	38606	Soil	USA
	A1	38607	Soil	USA
	A1	60439	*Lycopersicon esculentum*	United Kingdom
P. operculata		44952(T)	*Avicennia marina*	Australia
P. palmivora	A2	26200	Cacao	Costa Rica
	A1	26201	*Theobroma cacao*	Cameron
P. phaseoli		60171	Lima bean	USA
P. polymorphica		56966(T)	Fallen *Eucalyptus* sp. leaf	Australia

Table 1. (continued)

Name	Mating Type	ATCC No.	Host Plant/Substrate	Origin
P. porri		56616	Chrysantheumum	United Kingdom
		52729	*Allium porrum*	Netherlands
		38830	Carrot	Canada
P. primulae		56963	*Pyrus malus*	Unknown
P. pseudotsugae		52937(T)	Douglas fir	USA
		52938	Douglas fir	USA
P. quininea		56964(A)	*Cinchona officinalis*	USA
		46733(A)	*Cinchona officinalis*	USA
P. richardiae		46734	Unknown	Unknown
		60353(A)	*Zantedeschia aethiopica*	Unknown
P. sinensis	A2	46538(T)	Cucumber	China
P. spinosa var. *lobata*		28291(T)	Decaying *Rhizophora* leaf	Vietnam
P. spinosa var. *spinosa*		28294(T)	Decaying *Rhizophora* mangle leaf	USA
P. syringae		16709	Soil	USA
		14837	Fennel	Italy
P. vesicula		48641	submerged mangrove leaf	Unknown
P. vignae		46735(A)	Unknown	Australia
		42466	*Phaseolus angularis*	Japan

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[a] T = Type Culture; A = Authentic Culture

Table 2. Growth of Phytophthora Isolates on Various Culture Agar Media and Apple Fruit

Name	ATCC No.	Daily Growth Rate(a)				Apple(g) Inocu.	Relative Growth Rate(b)		Starch Utili.(c)	Cardinal Temp.(d)		Pigm. Prod.(e)	Colony Patterns		
		CM	V8	Malt	NO3		HMI	Mala.	(S.H.I.)	Min.	Max.		Malt	V8	PDA
P. aquatica	62088	7.6	9.0	2.8	2.2	3	101	76	83	1	5	2	3	3	3
P. areceae	46716	9.1	13.0	9.7	9.4	2	66	75	39	2	5	0	1	3	2
P. bahamensis	28296	1.4	1.8	0.9	3.0	0	0	0	0	2	5	0	3	2	0
	28297	1.6	2.0	1.5	0.9	0	0	0	0	2	5	0	3	2	3
P. batemanensis	56965	8.3	8.0	2.9	2.4	2	0	64	44	2	5	1	3	3	3
P. boehmeriae	52836	11.8	10.0	6.8	6.1	2	53	71	98	2	5	2	5	1	5
	46717	8.3	11.0	6.3	4.7	2	72	84	38	2	5	2	2	2	2
	60238	14.0	14.0	5.0	5.5	2	39	30	40	2	5	1	2	2	5
P. botryosa	58105	5.8	6.0	4.8	3.6	2	30	106	53	2	5	0	5	4	5
	58221	5.4	6.0	6.4	4.8	2	45	116	60	2	5	0	4	4	4
	26481	7.5	8.5	8.5	8.5	2	80	40	75	3	5	0	1	4	1
	62533	6.8	9.0	9.0	6.2	3	53	50	33	2	5	0	2	4	4
P. cactorum	52859	7.9	2.3	7.4	4.3	3	94	97	89	2	5	1	5	1	5
	62089	7.9	7.0	6.9	4.0	3	66	50	70	1	5	2	4	3	4
P. cambivora	38811	9.0	8.0	7.0	7.5	3	112	71	0	1	5	1	5	4	5
	46719	9.4	5.6	5.8	5.3	2	91	78	0	1	5	1	5	4	3
P. capsici	56600	6.2	11.0	4.4	5.3	3	127	143	56	2	5	2	4	4	3
	15399	12.5	9.0	5.7	2.2	3	120	117	40	2	5	0	4	3	4
	46012	11.7	11.0	7.3	1.7	2	112	130	0	2	5	0	5	3	5
	52776	13.6	12.0	12.0	7.4	3	410	57	68	1	5	0	4	3	1

Table 2. (continued)

Name	ATCC No.	Daily Growth Rate(a)				Apple(g) Inocu.	Relative Growth Rate(b)		Starch Utili.(c)	Cardinal Temp.(d)		Pigm. Prod.(e)	Colony Patterns		
		CM	V8	Malt	NO3		HMI	Mala.	(S.H.I.)	Min.	Max.		Malt	V8	PDA
P. cinnamomi	32992	14.1	14.0	8.2	5.5	3	72	36	0	2	6	0	3	4	4
	32993	14.0	15.0	4.8	5.5	2	72	36	0	2	6	0	3	3	5
	46671	9.8	10.0	54.0	7.2	2	50	70	0	1	5	0	3	4	4
P. citricola	52855	12.4	12.0	5.0	4.3	2	77	41	88	1	4	0	4	3	1
	28192	6.2	9.6	2.5	5.8	3	114	167	80	1	5	0	2	4	2
	52230	13.3	12.0	12.0	9.9	3	52	45	85	1	4	0	3	2	3
	46298	13.0	8.0	7.7	9.9	3	70	60	97	1	5	0	2	2	4
P. citrophthora	56195	16.0	14.0	19.9	5.9	3	53	36	86	2	5	2	2	3	4
	13613	13.7	12.0	11.0	6.5	3	85	21	93	1	5	1	2	3	4
	56599	8.4	8.0	8.9	5.6	3	102	58	94	1	5	1	2	3	4
P. clandestina	60438	2.3	3.0	0.0	1.0	3	0	0	90	2	4	0	0	4	0
P. colocasiae	56193	4.5	8.0	6.0	4.4	3	91	66	92	2	5	2	1	1	1
	52233	8.3	5.0	4.7	4.2	3	84	85	87	2	5	2	1	3	1
P. cryptogea	56962	13.2	11.0	11.0	5.4	3	120	28	64	1	5	1	1	3	1
	46721	12.7	12.0	11.0	10.0	3	141	38	98	1	5	1	4	3	4
	52404	15.0	15.0	13.0	9.7	2	152	44	83	1	5	2	3	3	3
P. drechsleri	46724	9.3	9.0	9.1	8.3	3	104	59	69	1	6	1	2	3	2
	26756	15.0	14.0	12.0	7.3	3	111	52	94	1	5	2	3	3	3
	15428	9.3	11.0	6.1	4.7	2	82	66	79	1	5	3	5	3	5
P. epistomium	28293	0.5	5.3	0.7	0.0	1	97	0	0	2	5	1	2	2	2
P. erythroseptica	58104	13.0	14.0	9.0	4.4	2	129	81	80	1	5	2	5	3	5
	16699	11.4	13.0	12.0	3.8	0	107	112	76	2	5	1	5	3	5

Table 2. (continued)

Name	ATCC No.	Daily Growth Rate(a)				Apple(g) Inocu.	Relative Growth Rate(b)		Starch Utili.(c)	Cardinal Temp.(d)		Pigm. Prod.(e)	Colony Patterns		
		CM	V8	Malt	NO3		HMI	Mala.	(S.H.I.)	Min.	Max.		Malt	V8	PDA
P. fragariae	58229	0.8	1.0	0.0	0.0	1	0	0	0	1	4	1	0	1	0
	11374	0.7	1.5	1.0	0.0	0	0	0	0	1	4	1	0	4	0
	13974	0.8	2.0	0.0	0.0	1	0	0	0	1	4	1	0	4	0
	13977	0.4	1.8	0.0	0.0	1	0	0	0	1	4	1	0	3	0
P. gonapodyides	46726	8.0	8.0	4.7	2.0	3	116	68	96	1	5	1	2	3	3
	60351	5.5	6.0	3.9	2.8	3	89	55	92	1	5	1	2	3	3
P. heveae	16700	8.2	9.3	7.9	5.8	1	57	11	0	3	5	1	2	2	2
	58515	8.9	7.0	7.4	6.5	2	83	67	0	3	5	1	5	2	1
P. hibernalis	56353	7.2	7.5	1.9	4.5	2	45	0	0	1	4	0	4	3	4
	32995	4.6	9.2	1.8	2.2	2	47	0	0	1	4	0	1	4	1
	60352	4.8	9.0	2.1	1.6	2	43	63	0	1	4	0	5	4	5
P. humicola	52179	8.9	10.0	4.0	5.5	2	89	34	0	1	4	1	3	2	3
P. ilicis	56615	3.3	3.4	0.0	3.3	2	0	0	0	1	4	0	0	4	0
P. infestans	32835	7.2	12.0	2.3	0.4	1	50	117	0	1	5	1	5	2	5
	16980	7.5	4.0	0.0	0.9	0	0	0	0	2	5	2	5	3	0
	48718	6.6	3.5	2.2	1.5	2	46	94	0	2	5	1	5	2	5
	60180	7.1	11.0	3.0	2.3	2	65	80	0	2	5	2	5	3	5
P. insolita	38789	7.7	6.0	2.1	4.2	3	93	75	0	2	6	3	5	2	3
P. iranica	60237	5.9	6.4	3.1	4.5	1	71	103	93	3	5	2	5	3	5
P. katsurae	58598	4.2	8.8	8.8	4.8	3	135	188	0	2	5	3	5	1	4
	36818	2.4	12.0	9.6	8.4	3	89	36	0	1	5	3	5	1	5

Table 2. (continued)

Name	ATCC No.	Daily Growth Rate(a)				Apple(g) Inocu.	Relative Growth Rate(b)		Starch Utili.(c)	Cardinal Temp.(d)		Pigm. Prod.(e)	Colony Patterns		
		CM	V8	Malt	NO3		HMI	Mala.	(S.H.I.)	Min.	Max.		Malt	V8	PDA
P. lateralis	58399	4.2	5.0	5.1	3.1	2	94	15	0	1	4	2	1	2	1
	58816	4.4	5.0	2.7	3.0	2	72	0	0	1	4	1	1	2	1
P. meadii	58103	9.3	11.0	46.0	8.4	1	66	126	74	3	5	0	2	3	1
	52236	8.1	8.0	7.3	5.8	1	89	70	91	3	5	0	1	3	1
P. megakarya	42100	9.6	4.4	7.2	5.6	2	12	0	0	2	5	0	5	1	5
	46728	9.5	6.3	5.5	12.0	2	58	63	0	2	5	2	5	2	5
P. megasperma	38828	10.9	10.0	11.0	4.4	3	104	47	38	1	5	2	3	3	1
	58969	9.8	6.6	6.1	5.0	0	95	50	62	1	5	2	5	3	5
	48609	6.9	7.0	3.7	3.3	0	46	38	53	1	5	0	5	3	2
	58817	7.4	7.0	7.4	6.6	1	38	96	47	1	5	3	5	1	5
	16706	5.5	7.8	2.0	3.0	0	46	60	54	2	5	2	5	1	5
	44390	12.8	10.0	10.0	84.0	0	69	0	77	1	5	2	5	3	5
P. melonis	58427	4.0	2.0	13.0	7.3	3	80	91	0	2	6	0	5	2	5
	52854	8.4	12.0	10.0	8.0	3	125	38	0	1	6	0	3	2	3
P. mexicana	46731	7.2	9.0	7.2	8.3	2	89	108	29	2	5	0	5	4	2
P. nicotianae	38606	7.3	8.0	4.1	4.0	3	66	55	49	2	6	2	2	2	2
	38607	7.5	8.0	1.8	3.7	3	60	61	65	2	6	1	4	3	2
	60439	3.8	7.6	3.4	5.8	3	66	43	80	2	5	1	3	3	3
P. operculata	44952	5.0	3.0	2.0	3.0	3	20	41	0	2	5	1	0	2	5
P. palmivora	26200	9.0	7.0	3.9	5.5	2	69	67	78	2	5	2	4	1	4
	26201	7.7	9.0	4.4	5.4	2	68	64	0	2	5	2	3	4	2

Table 2. (continued)

Name	ATCC No.	Daily Growth Rate(a)				Apple(g) Inocu.	Relative Growth Rate(b)		Starch Utili.(c)	Cardinal Temp.(d)		Pigm. Prod.(e)	Colony Patterns		
		CM	V8	Malt	NO3		HMI	Mala.	(S.H.I.)	Min.	Max.		Malt	V8	PDA
P. phaseoli	60171	4.3	2.0	1.0	0.0	3	0	0	0	2	4	0	0	0	0
P. polymorphica	56966	8.2	9.0	6.7	4.7	3	95	69	97	1	5	3	3	2	3
P. porri	56616	6.3	8.0	4.2	2.2	0	0	14	97	1	4	3	5	3	5
	52729	5.8	7.0	4.7	4.1	0	15	0	0	1	4	3	3	4	4
	38830	5.3	5.0	3.6	2.4	0	8	7	89	1	4	3	3	4	4
P. primulae	56963	4.0	5.0	3.5	1.8	2	100	128	0	1	5	1	3	3	2
P. pseudotsugae	52937	8.0	10.0	7.8	6.4	3	72	13	72	1	4	0	3	2	3
	52938	8.0	8.0	5.6	6.0	3	37	11	77	1	4	0	3	2	1
P. quininea	56964	6.0	6.0	5.3	5.7	2	94	101	0	2	5	0	4	2	1
	46733	8.5	7.4	6.3	5.0	3	96	88	0	2	5	0	1	2	4
P. richardiae	46734	10.1	10.0	10.0	7.3	1	97	22	0	1	5	0	5	3	5
	60353	6.7	4.0	5.3	6.1	3	73	83	0	2	5	0	5	2	5
P. sinensis	46538	6.8	9.0	9.1	4.8	2	38	43	42	2	5	1	5	2	5
P. spinosa var. lobata	28291	3.8	2.2	3.2	0.8	1	32	32	0	1	5	1	2	3	2
P. spinosa var. spinosa	28294	2.3	4.5	4.2	3.8	1	133	138	0	1	5	0	1	3	1
P. syringae	16709	8.5	9.0	7.1	5.7	2	97	13	0	1	4	2	2	3	2
	14837	3.7	6.0	5.0	6.4	1	24	65	86	1	4	2	5	1	1

Table 2. (continued)

Name	ATCC No.	Daily Growth Rate(a)				Apple(g) Inocu.	Relative Growth Rate(b)		Starch Utili.(c)	Cardinal Temp.(d)		Pigm. Prod.(e)	Colony Patterns		
		CM	V8	Malt	NO3		HMI	Mala.	(S.H.I.)	Min.	Max.		Malt	V8	PDA
P. vesicula	48641	4.3	5.0	4.1	3.1	2	64	62	64	2	5	0	2	3	3
P. vignae	46735	4.7	7.7	2.0	3.4	0	106	0	82	2	5	0	5	2	5
	42466	6.7	7.0	2.9	4.8	0	107	0	72	2	5	0	5	4	5

Notes for Table 2:

(a) Daily growth rate (mm/day) was calculated from formula: d2-d1 /number of days between d1 and d2. d1 was the colony diameter 3 days after inoculation while d2 was the one 2-3 days later.

(b) Relative growth rate: (daily growth rate on either HMI or malachite green medium/daily growth rate on CM agar medium) x 100.

(c) Starch Hydrolysis Index (S.H.I.) = (diameter of clear zone after flooding with iodine solution/diameter of fungal colony) x 100

(d) Minimal temperatures ranked as following: 1 = under under 5 C; 2 = 5 -10 C; 3 = 10-15 C. Maximum temperatures ranked as following 4 = 25-30 C; 5 = 30-35 C; 6 = over 35 C.

(e) The degree of brown pigmentation produced on Timmer's tyrosine-casein hydrolysate agar medium after 3 - 4 weeks was ranked as following: 0 - none; 1 - slight; 2 - moderate; 3 - abundant.

(f) Colony patterns on malt and PDA were classified as following: 0 - no growth; 1 - radiate (uniformly radiate hyphae); 2 - chrysanthemum (narrow petaloid sectors); 3 - rose or camellia (broad, rounded petaloid sectors); 4 - stellate (intermediate between radiate and chrysanthemum); 5 - uniform (without any obvious pattern). Growth pattern on V8 agar medium was classified as following: 1 - not fluffy; 2 - slightly fluffy; 3 -moderately fluffy; 4 - highly fluffy.

(g) Growth on wounded McIntosh apple fruit after 2 wk:
0 - no infection; 1-lesion diam under 20 mm; 2-lesion diam 20-50 mm; 3-lesion diam over 50 mm

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WHAT IS OCHROPORUS OSSATUS (HYMENOCHAETACEAE)?

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A.S. Bondarzew stated in 1912 that there may be several biological varieties of *Fomes (= Phellinus) igniarius* (L.) Fr. specialized on certain tree species, each having characteristic basidiomata. However, he noted (1912: 17) that this idea has been influenced by the views of J. Eriksson on biological forms in *Puccinia graminis*. He described (in Russian) five new forms and illustrated them with figures and photographs: f. *Alni*, f. *Betulae*, f. *Tremulae*, f. *Quercus* and f. *Pruni* (syn. *Fomes fulvus* (Scop.) Fr.). The three last mentioned forms are currently recognized as *Phellinus tremulae* (Bond.) Bond. & Boriss., *Ph. robustus* (P. Karst.) Bourd. & Galz. and *Ph. tuberculosus* (Baumg.) Niem., respectively. The first two forms *(f. alni*, f. *betulae)* as well as f. *salicis* and f. *piri* (on *Malus* and *Sorbus)* described by Bondarzew in 1934 have long been considered to be more or less easily distinguishable forms of *Fomes/Phellinus igniarius*.

In 1963 E. Parmasto stated that *Ph. igniarius* f. *igniarius* was the correct name for f. *salicis* Bond., and this was accepted by subsequent authors (e.g., Niemelä, 1975: 109). However, this was merely a name correction: Bondarzew himself never distinguished the "typical" *igniarius* as f. *igniarius*.

Of the four forms mentioned above f. *alni* deserves special attention. It is widespread in East Europe and has been described repeatedly: by Bondarzew (1934, 1953), Domański, Orłoś & Skirgiełło (1973), and in a number of handbooks on forest pathology published in the USSR.

In 1975 T. Niemelä raised f. *alni* to the rank of a variety of *Ph. igniarius;* he also gave a well illustrated description of the development of one specimen of this variety in 1986. In 1976 Parmasto raised it to specific rank *(Ph. alni* (Bond.) Parm.) and stressed one of the characteristics easily noticeable macroscopically: there is a "more or less well developed, densely zonate 'core' seen in the basidiocarp sections, especially in the oldest part, or context relatively thick and zonate". As an independent species, *Ph. alni* was described and illustrated also by M.A. Bondarceva *(in* Bondarceva & Parmasto, 1986); Fiasson & Niemelä recognized it as a species of the genus *Ochroporus (O. alni* (Bond.) Fiass. & Niem.).

Bondarzew did not designate a type for his f. *alni* in 1912 or subsequently; however, the protologue of his taxon includes also a sketch (fig. 1) and a photograph of a specimen (Tab. 1, f. 2) named in the legend (on p. 55) as 'type'. There has not been any confusion with this taxon; however, Bondarzew has confirmed the identifications of this form made by several mycologists in the USSR (including M.A. Bondarceva, E.P. Komarova, E. Parmasto, a.o.).

Obviously the same taxon *(Fomes igniarius* f. *alni, Phellinus alni)* was recently described twice by M. Fischer as a new species: under the name *Ochroporus ossatus* Fischer *(in* Nuss, 1986: 159) and some months later as *Phellinus ossatus* M. Fischer (Fischer, 1987: 37). The second name is illegitimate and is to be rejected as it is based on the same holotype (MTB 6945/3) as the first named species (cf. Voss et al., 1983, Art. 63.1). It may not even be considered to be a new combination *Phellinus ossatus* (M. Fischer) M. Fischer: it has not been validly published (basionym not indicated as required by Art. 33.2 of the ICBN).

Why did Fischer describe a new species instead of using the available name *(Phellinus) alni?* The only argument given by him is that its type has not been designated by Bondarzew and that Niemelä (1975: 110) has not found any representative material of this taxon in the Leningrad herbarium (LE).

Certainly a holotype for every taxon described after Jan. 1, 1958 (ICBN, Art. 37) must be kept in a herbarium. But f. *alni* was described in 1912! If the lack of a type specimen is a reason for considering a taxon to be illegitimate, hundreds of Friesian species could be deleted by any mycologist who wants to publish "new" species. Designation of a neotype would be the proper way to proceed in such cases.

Fischer's new species is typified by a specimen collected on *Malus domestica;* according to one part of the description it is the same as *Fomes igniarius* f. *piri* Bond. (1934). Another part of the description is in accordance with f. *alni* Bond. (1912). The author of this paper has kept these two taxa separate until now, though with some doubt. Fischer in his book (1987: 34-35) has demonstrated that the monosporous strains obtained from basidiomata growing on *Alnus incana, A. glutinosa, Corylus avellana, Malus domestica* and *Prunus padus* were compatible in all combinations; consequently he noted (Fischer, 1987: 35) that the new species was described for the collections from all the hosts (substrata) mentioned above. However, according to the data given by him on pp. 14, 33 and 34, the type of *Ochroporus ossatus* was intercompatible (conspecific) with the specimens collected and determined by Niemelä and Parmasto as *Phellinus alni*.

This is not the place to discuss the taxonomy of the Hymenochaetaceae on generic level; nevertheless, one may ask why I use the genus name *Phellinus* for *alni* instead of *Ochroporus* proposed by Fiasson & Niemelä (1984) in their fundamental paper on the taxonomy of European poroid Hymenochaetales. The division of *Phellinus* s. l. proposed by these authors seems to be partly more or less well founded (the genera *Fomitiporia* Murr. and *Fuscoporia* Murr.) but not convincing enough in the treatment of the *Phellinus-Porodaedalea-Ochroporus-Phellinidium* complex. The phenetic analysis presented on pp. 17-18 in their paper does not give any sound grounds for distinguishing these four genera, and I doubt if the phenetic approach may be used as the main basis for distinguishing genera in this group. The number of species Fiasson and Niemelä studied is quite limited and the use of the cladistic method employed by them was also not very correct. It has been asserted that "arbitrary criteria and authoritarian acceptance simply do not enter in" phylogenetic systematics (cladistics) which makes use of simple analytic methods (Schafersman, 1985). Alas! We do not have enough trustworthy data to decide which character states are apotypic and which are plesiotypic in the Hymenochaetaceae. For example, Fiasson and Niemelä state that pileate habit, oval form and average size of spores are plesiomorphic states; resupinate habit, subglobose form and small size of spores are apomorphic states of the characters studied. I am convinced in the opposite view; however, these alternative standpoints are both arbitrary, and in such cases cladistic methods simply do not work. So let us not be in a hurry with taxonomic replacements of the species dealt with in this paper.

The author is greatly indepted to Dr. D.A. Reid for reviewing the manuscript.

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NOTES ON HYPHOMYCETES. LVIII. SOME DEMATIACEOUS TAXA, INCLUDING TWO UNDESCRIBED SPECIES OF CLADOSPORIUM, ASSOCIATED WITH BIODETERIORATION OF CARPET, PLASTER AND WALLPAPER

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ABSTRACT

A number of dematiaceous hyphomycetes, belonging to the genera *Alternaria*, *Cladosporium*, *Curvularia*, *Drechslera*, *Stachybotrys* and *Ulocladium*, in addition to species of *Acremonium*, *Aspergillus*, *Chaetomium*, *Penicillium* and *Phoma*, were isolated from wallpaper, carpet and plaster undergoing biodeterioration in hotels in the southeastern United States. Two new species of *Cladosporium*, *C. geniculatum* Morgan-Jones and *C. breviramosum* Morgan-Jones, encountered during the course of the study, are described and illustrated. Comments are offered on the genus *Cladosporium* as presently constituted.

INTRODUCTION

Voluminous writings exist on the subject of biodegradation of natural polymers, such as cellulose, chitin and lignin, which are relatively stable substances that do not readily break down. The role of fungi in the process of decomposition of such substances in natural ecosystems is well known (Lindeberg, 1946; Kendrick and Burges, 1962; Dickinson and Pugh, 1974). During the past two decades, increasing attention has been paid to the role of fungi in deterioration of man-made, or partly man-made materials, including plastics (for example by Awao *et al.*, 1971; Kestel'man *et al.*, 1972; Nyvkist, 1974; and Kavelman and Kendrick, 1978). Although not all experimental results have been consistent, and a number of conflicting reports exist in the literature, it has been shown that physical changes in plastic materials can be induced by fungal activity (Kestel'man *et al.*, 1972). In general, however, a consensus has emerged that synthetic polymers are highly resistant to biodegradation and where this occurs, decomposition is slow (Nyvkist, 1974).

In recent years, biodeterioration of the internal fabric of buildings and of partly man-made materials such as textiles and paper has commanded attention in many parts of the world. A substantial number of reports, including documentation of implicated fungi, have appeared. Miller and Holland (1981), for example, reported isolating thirty-nine fungal species, many cellulolytic, from various surfaces, including cloth, wallpaper and plaster, in two Canadian historic houses subjected to different environmental controls. Many of the

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species encountered were said to have been previously found to be biodeteriogenic. Among those isolated most frequently were species of *Alternaria* Nees, *Aspergillus* Mich., *Cladosporium* Link, *Penicillium* Link, *Phoma* Sacc. and *Trichoderma* Pers. Two species isolated from plaster, *Alternaria alternata* (Fr.) Keissler and *Cladosporium herbarum* (Pers.) Link, were said to be often found growing on the surface of that substrate under damp conditions. A second species of *Cladosporium*, *C. cladosporioides* (Fres.) de Vries, was found frequently on cloth. Two species of *Ulocladium* Preuss, *U. botrytis* Preuss and *U. alternariae* (Cooke) Simmons, were isolated from wallpaper. The former has been reported from a variety of substrates, including rotten wood, paper and textiles (Ellis, 1971), whereas the latter was previously known only from its type collection on damp wallpaper in the United Kingdom (Cooke, 1871; Simmons, 1967; Ellis, 1976). Strezelezyk (1981) reviewed aspects of the biodeterioration of paintings and sculptures. Other examples of similar studies include the following. Marcheva (1985) reported isolation of *Alternaria alternata*, *Cladosporium herbarum* and *Stemphylium botryosum* Wallr. [anamorph of *Pleospora herbarum* (Pers.) Rabenh.] from damaged paper documents in the Bulgarian state archives and discussed their cellulolytic activity. In the same year, Ohtsuki (1985) stated that species of *Chaetomium* Kunze, *Cladosporium*, and *Penicillium* are often isolated from stain spots on flooded papers and fabrics in Japan. Dhawan and Agrawal (1986) encountered species of *Acremonium* Link, *Alternaria*, *Aspergillus*, *Chaetomium*, *Cladosporium*, *Fusarium* Link, *Paecilomyces* Bain. and *Penicillium* on miniature paintings and lithographs in India. Jeffries (1986) found biodeterioration of mural paintings in Canterbury Cathedral, England, to be caused by *Beauvaria alba* (Limber) Saccas, a species whose type isolate originated from a mixed culture with *Penicillium jensenii* Zaleski [as *Penicillium intricatum* Thom, which was thought by Raper and Thom (1949) to be *P. godlewskii* Zaleski, a binomial now considered to be a synonym of *P. jensenii* (Pitt, 1979)] obtained from a book cover in the U.S.A. (Limber, 1940; de Hoog, 1972). The fungus was thought to utilize organic binders present in the original paint preparation. In the same study an unnamed species of *Cladosporium* grew out from one plaster sample.

It is apparent from the literature that a restricted but consistent group of fungi is associated with biodeterioration of such substrates as paper, textiles and plaster. The implicated taxa are diverse in terms of classification, ranging from the ascomycete genus *Chaetomium* to dematiaceous hyphomycetes such as *Alternaria*, *Cladosporium* and *Ulocladium*, other hyphomycetous genera such as *Acremonium*, *Aspergillus* and *Penicillium*, and the pycnidial genus *Phoma*.

During the course of a preliminary survey of fungi causing damage to vinyl wallpaper, carpeting, plaster-board and plaster in several hotels in the southeastern United States, a number of taxa have been isolated (Table 1). Stained and damaged wallpaper, together with discolored carpeting and plaster, all resulting from damp conditions in hotel guest rooms, were sampled. In no situation was free water available. The moisture problems were predominantly associated with warm, moist outside air and air conditioning or with condensation on cold or chilled water pipes in the walls. Some of the fungi found, such as *Alternaria alternata*, *Drechslera halodes* Subram. & Jain and *Stachybotrys atra* Corda, are common, ubiquitous dematiaceous hyphomycetes known previously from foodstuffs, paper and textiles (Ellis, 1971). Others, such as *Ulocladium alternariae*, have rarely been found while two, belonging to *Cladosporium*, are novel. In the case of carpeting and wallpaper, fungi occurred predominantly on the under surface of the substrate and, in particular instances, individual fungi predominated. Some of the fungi occurring on wallpaper could possibly have been utilizing, as a food source, the adhesive paste applied to it. Others appeared to penetrate the substrate and their presence could be detected by substantial discoloration. The new species of *Cladosporium* encountered are described herein. Attempts to isolate the species of *Cladosporium* in pure culture were only partly successful, since conidia of one could not be induced to germinate. Those of the other did so readily. Since all the essential features can be discerned from the collection made, the species not isolated is described from the substrate on which it was found. It is hoped that it will be isolated at a later date if a viable collection is obtained.

TABLE 1. Fungi found on carpet (C), plaster-board (P), and wallpaper (W).

Location	Substrate	Species
Cabot Lodge, Tallahassee, FL	C	*Phoma herbarum* *Stachybotrys atra*
	W	*Chaetomium globosum* *Penicillium simplicissimum* *Stachybotrys atra*
Airport Holiday Inn, Jacksonville, FL	P	*Acremonium strictum* *Alternaria alternata* *Aspergillus versicolor* *Cladosporium geniculatum* *Penicillium glabrum*
King and Prince Hotel, St. Simon's Island, GA	W	*Aspergillus fumigatus* *Cladosporium breviramosum* *Curvularia lunata* *Drechslera halodes* *Penicillium simplicissimum* *Stachybotrys atra* *Ulocladium alternariae*

MATERIALS AND METHODS

Representative samples of moldy or substantially discolored carpet, plaster and wallpaper were removed from ceilings, walls and floors of guest rooms, transported to the laboratory, and incubated in moist chambers [sterile Petri dishes containing three layers of filter paper soaked in sterile distilled water]. After four days at 25C, the samples and surrounding filter paper were examined for the presence of fungi and microscopic preparations in the form of slides were made as appropriate. Following initial observation and tentative identity determination, fungi encountered were isolated into pure culture. Dematiaceous hyphomycetes were isolated by removing conidia from conidiophores with a sterile needle and transferring them to potato dextrose agar plates containing 1.5 percent streptomycin sulfate to deter bacterial growth. All dematiaceous hyphomycetes, with the exception of the *Cladosporium* growing on plaster, grew out onto the filter paper and, in most instances, pure colonies were apparent, making isolation relatively easy. Plate cultures for colony descriptions and radial growth measurements were prepared on PDA and MEA by removing discs, 7 mm in diameter, obtained just behind the growing edge of a colony using a sterile cork borer, and transferring them singly to fresh plates. Colony colors were determined according to the color ranges of Kornerup and Wanscher (1978). Determinations of colony color were made in daylight, as recommended by Pitt (1979), and directly against a white background.

TAXONOMIC PART

Cladosporium geniculatum Morgan-Jones sp. nov. (Figure 1)

Coloniae effusae, atrobrunneae vel atrae, densae, fuligineae, crustaceae vel pulveraceae. Mycelium plerumque superficiale, ex hyphis repentibus, ramosis, septatis, laevibus, pallide brunneis, 2-3.5 µm crassis compositum. Hyphae ex cellulis inflatis interdum compositae. Conidiophora semimacronemata vel macronemata, mononemata, ex apice lateribusque hypharum saepe ex cellulis inflatis oriunda, plerumque simplicia, recta vel flexuosa, saepe geniculata, septata, medio brunnea, laevia, crasse tunicata, apicem versus cicatricibus ornata, usque ad 64 µm longa, 3-4.5 µm crassa. Cellulae conidiogenae holoblasticae, polyblasticae, in conidiophore integratae, cylindricae, indeterminatae, terminales vel intercalares. Conidia solitaria vel catenata, in catenas ramosas formata, sicca, medio brunnea, globosa, subglobosa, vel ellipsoidea, laevia, 0-1 septata, ad bases cicatrice protrudenti et at apices 1-2 cicatricibus protrudentibus, basi plerumque papillata, 5-8 µm X 5-6 µm, ramiconidia usque ad 11 µm longa.

In gypso, Airport Holiday Inn, Jacksonville, Florida, U.S.A., December 1987, B.J. Jacobsen, AUA, holotypus.

Colonies effuse, dark brown to black, dense, crustaceous or powdery, appearing as sooty patches on the dry surface of the substrate. Mycelium mostly superficial, composed of repent, branched, septate, smooth, pale brown, 2-3.5 µm wide hyphae. Individual terminal or intercalary hyphal cells sometimes inflated to 6-7.5 µm wide, becoming thick-walled, mid-brown and chlamydospore-like. Short chains of inflated cells sometimes present but these never becoming as large or as heavily pigmented as when occurring individually. Conidiophores semimacronematous or macronematous, often not distinguishable from the vegetative mycelium except in the fertile portion, mononematous, arising terminally or mostly laterally from the repent superficial hyphae, sometimes from inflated cells, usually unbranched, straight or flexuous, frequently geniculate, with one or more knee-like bends distally, septate, mid-brown, smooth, relatively thick-walled, bearing a number of conidial scars in the upper, fertile part, up to 60 µm long, 3-4.5 µm wide. Conidiogenous cells holoblastic, monoblastic, integrated, terminal or intercalary, indeterminate where terminal, cylindrical, sympodial or unsynchronized, bearing up to nine scars, frequently protruding at the conidiogenous loci. Conidia solitary or, more frequently, catenate, dry, mid-brown, smooth, globose or subglobose, unicellular or, when ramiconidia, ellipsoidal or clavate and 1-septate, with a single protuberant, thin, basal scar where produced terminally on a chain, with a single scar at each end where intercalary in position, or with a single scar at the base and two apically where a ramiconidium, base sometimes somewhat papillate, 5-8 µm X 5-6 µm, with an occasional ramiconidium up to 11 µm long.

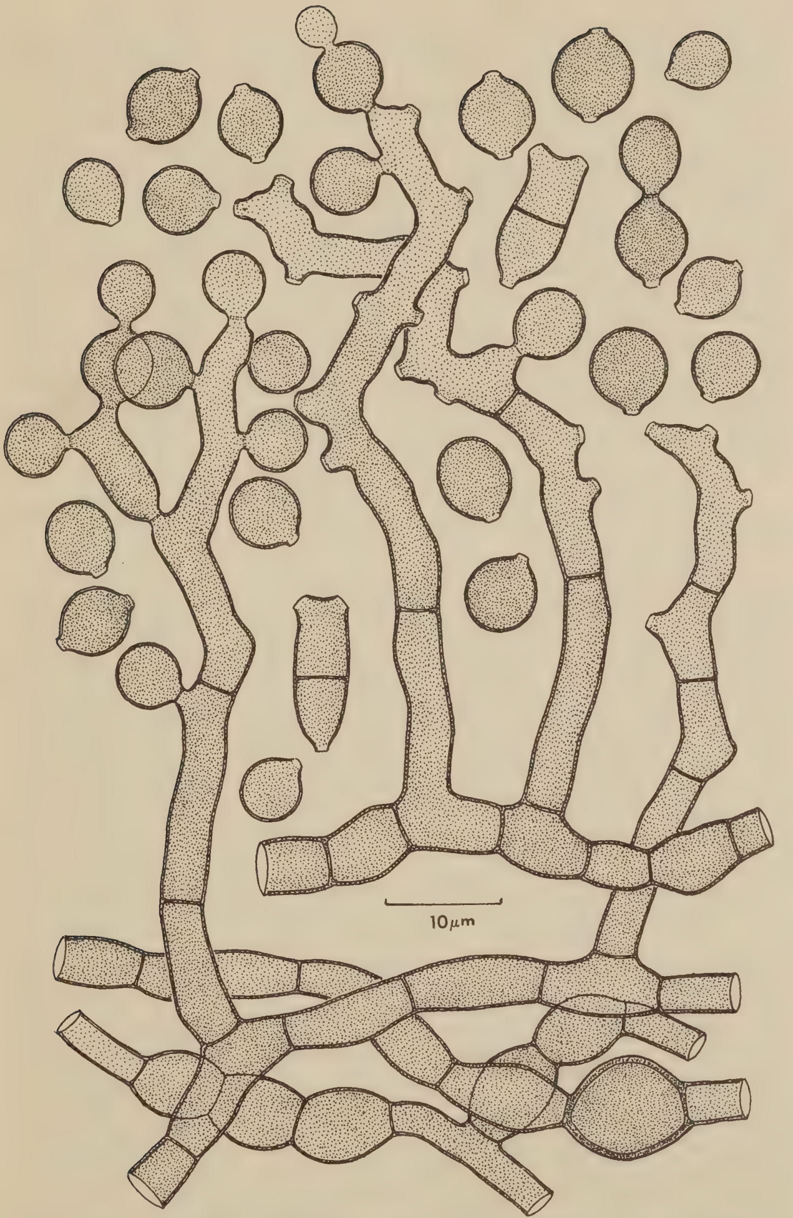


FIGURE 1. *Cladosporium geniculatum*. Hyphae, conidiophores and conidia.

On plaster; North America.

Collection examined: on discolored wall plaster, Airport Holiday Inn, Jacksonville, Florida, U.S.A., December 1987, B.J. Jacobsen, AUA, type.

Cladosporium breviramosum Morgan-Jones sp. nov. (Plate 1, figure 2)

Coloniae effusae, avellaneae vel griseo brunneae, gossypinae vel breviter pilosae. Mycelium plerumque superficiale, ex hyphis ramosis, septatis, laevibus vel verruculosis, pallide brunneis, 2.5-3.5 µm crassis compositum. Coloniae in agaro decocto tuberorum velutinae, pallide griseo brunneae, post 10 dies 25C ad 38 mm diametro; reverso atro brunneo vel atro. Conidiophora macronemata, mononemata, erecta, recta, rigida, cylindrica, crasse tunicata, verruculosa vel verrucosa, septata, medio brunnea, apicem versus pallidiora et 1-2 ramosa, usque ad 360 µm longa X 4-6 µm crassa, ad bases 8-10 µm crassa, apices versus 3-4 µm crassa. Cellulae conidiogenae holoblasticae, polyblasticae, terminales, in conidiophoris incorporatae vel discretae, pallide brunneae vel subhyalinae, laeves vel verruculosae, cylindricae vel clavatae, cum 1-3 cicatricibus, incrassatis, sessilibus; cellulae discretae 12-22 µm longae. Conidia catenata, in catenas ramosas formata, subhyalina, laevia, ellipsoidea vel fusiformia, aseptata, 3-6 X 2-3 µm; ramoconidia clavata, 8-11 X 4-4.5 µm.

In papyrus parietis, King and Prince Hotel, St. Simon's Island, Georgia, U.S.A., December 1987, B.J. Jacobsen, AUA, holotypus.

Colonies effuse, covering large areas of the substrate, hazel-brown to brownish-grey, becoming darker with age, cottony or shortly hairy, conidial heads lighter, beige to light buff. Mycelium predominantly superficial, composed of branched, septate, smooth or minutely verruculose, pale-brown, 2.5-3.5 µm wide hyphae. Colonies on potato dextrose agar [Difco] (Plate 1, A) velvety, flat, when young Nougat (5D3), becoming Drab Mouse Grey (5E3) with age, generally evenly colored except for a 2 mm wide, Nutria (5F3) margin, after 14 days Brownish Beige / Saruk (6EA) with a Chocolate (Brown) (6F4) margin and Light Brown (6D8) at the extreme periphery, attaining a diameter of 36 mm at 20 C after 10 days, 38 mm at 25C, and 52 mm at 30C, discoloring the agar pale yellowish-brown [Golden (4C6) to Pompeian Yellow (5C6)] at 25C; reverse blackish-brown to black. After three weeks colonies on PDA generally uniformly colored, without a darker margin. Colonies on malt extract agar [Difco] Olive Brown (4E6), thin, with very little aerial mycelium except for scattered conidiophores, but sporulating abundantly, attaining a diameter of 40 mm on MEA at 25C after 7 days (Plate 1, B); reverse pale olivaceous to smoky grey. Conidial masses dry, cream colored *in vitro*. Conidiophores macronematous, mononematous, erect, straight, rigid, cylindrical, thick-walled, verruculose to verrucose or sometimes tuberculate (Plate 1, D & E), particularly distally, septate, mid-brown, paler towards the apex, up to 360 µm long X 4-6 µm wide, 3-4 µm wide at the extreme apex, 8-10 µm wide at the base, bearing one or two lateral, fertile, unicellular metula-like branches subterminally. Where two branches are present, they originate opposite each other at the same level, immediately below a septum delimiting the terminal cell of the conidiophore, in a manner similar to those common in *Paecilomyces* and *Penicillium*. Conidiophores on PDA generally a little wider than those on the substrate but slightly thinner-walled and variable; semimacronematous, subhyaline conidiophores produced on this medium in addition to the typical macronematous form. Conidiogenous cells holoblastic, polyblastic, terminal,

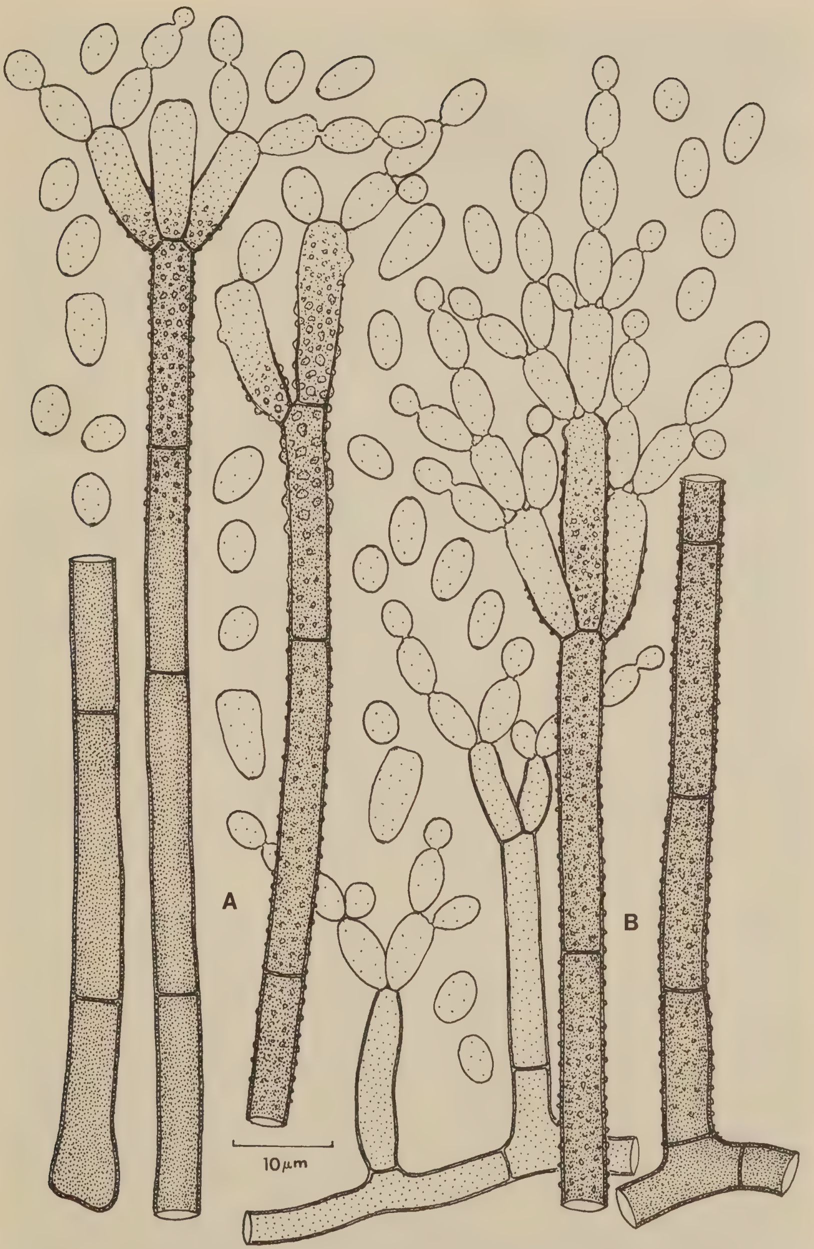


FIGURE 2. *Cladosporium breviramosum*. A, Conidiophores and conidia from wallpaper substrate; B, same from culture on PDA.

incorporated in the conidiophore as lateral branches, pale brown to subhyaline at the apex, smooth or verruculose towards the base, cylindrical or clavate, straight or slightly curved when lateral, with one to three thin, terminal or lateral, sessile scars, where scars are lateral often on a small protuberance; lateral discrete cells 12-22 µm long. Conidia in branched chains, subhyaline, smooth, ellipsoid or fusiform, aseptate, with small, thin, not easily discernible scars, 3-6 X 2-3 µm; ramiconidia short-clavate, 8-11 X 4-4.5 µm.

On rotting wallpaper; North America.

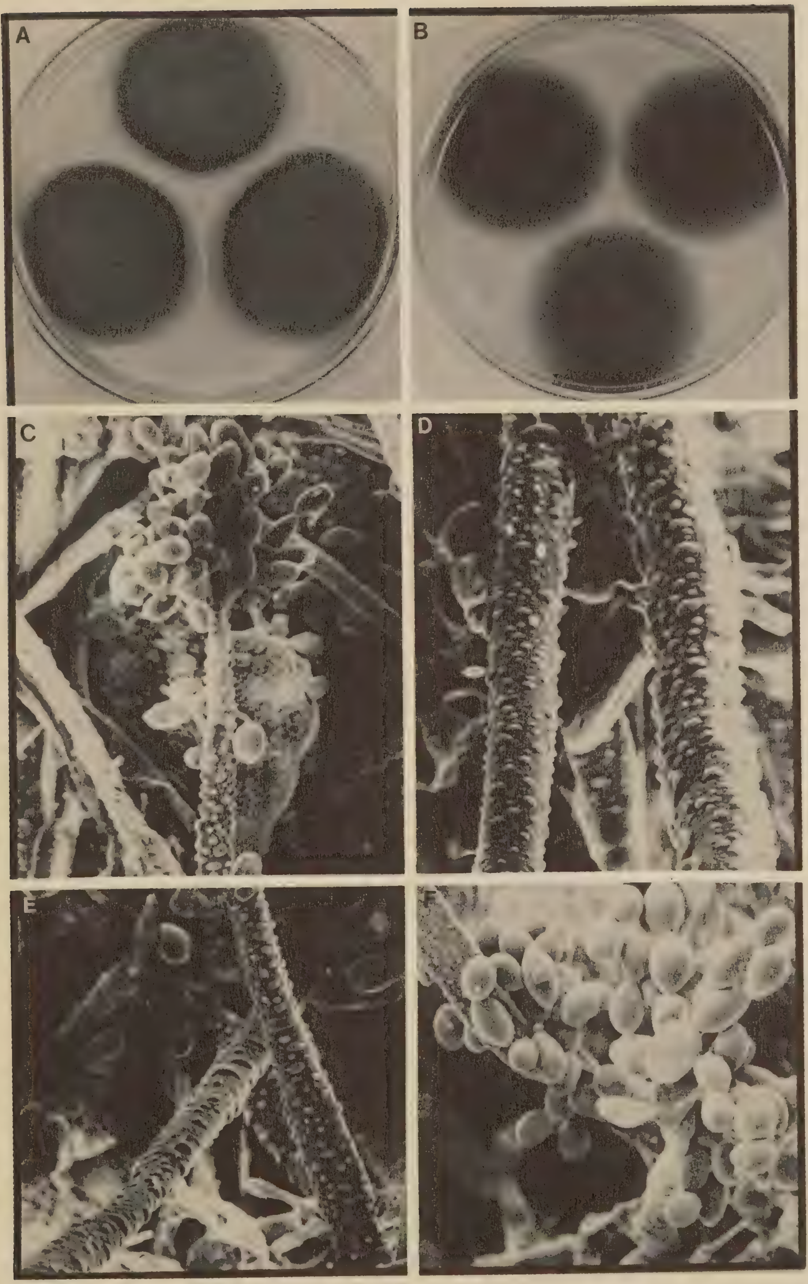
Collection examined: on discolored wallpaper, King and Prince Hotel, St. Simon's Island, Georgia, U.S.A., December 1987, B.J. Jacobsen, AUA, type [isolate derived from this collection deposited at ATCC].

DISCUSSION

When compared with the many species of *Cladosporium* Link described to date, *C. geniculatum* has a notably distinctive morphology. The combination of a strikingly geniculate conidiophore, recognized in the choice of its specific epithet, and globose, mid-brown, relatively thick-walled conidia serves to easily distinguish it. *Cladosporium bisporum* Matsushima, described from dead leaves of plantain banana [*Musa paradisiaca* L.] collected in Okinawa, Japan, bears some resemblance to *C. geniculatum* but differs in several important respects. In that species, conidia, which are shaped and pigmented similarly to those of *C. geniculatum*, are produced in pairs. A terminal, subglobose or obovoid conidium is invariably subtended by a single fusiform conidium (Matsushima, 1975). The conidiogenous loci, in contrast to those of *C. geniculatum* which are scattered more or less evenly over the terminal, fertile portion of the conidiophore, tend to be localized in clusters at swollen nodes in *C. bisporum*. An additional distinction lies in the fact that the latter produces a *Dactylaria* synanamorph. The conidiophores of *C. macrocarpum* Preuss have something of the aspect of those of *C. geniculatum* in being brown and somewhat geniculate. The conidial scars on the conidiophore in that species are, however, very dark and its olivaceous brown, densely verrucose, frequently septate conidia are distinctive. (Domsch *et al.*, 1980; Matsushima, 1985). Among species of *Cladosporium* reported from artificially created ecological niches and broadly similar environments, *C. leprosum* Morgan-Jones resembles *C. geniculatum* in producing colonies of identical gross appearance. That species forms clusters of swollen hyphal cells in the form of rudimentary stromata from which conidiophores arise. Its conidia differ from those of *C. geniculatum* in being much paler and mostly ellipsoid to doliiform in shape.

Cladosporium breviramosum is easily distinguishable from other species of the genus by a combination of several characteristics. Many of the species known *in vitro* have olivaceous or greyish green colonies. Among those having colonies in various shades of brown or greyish brown, *C. breviramosum* bears some similarity in coloration to *C. avellaneum* de Vries, judging from the description of that species published by de Vries (1952). It is interesting to note that *C. avellaneum* was reported to produce a diffusing brown pigment since colonies of *C. breviramosum*, grown on PDA at 25C, discolor the agar, giving a

PLATE 1. *Cladosporium breviramosum*. A, 10-day-old colonies on PDA at 25C; B, 7-day-old colonies on MEA; C-F, scanning electron micrographs of conidiophores and conidia.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yellowish-brown hue. In the absence of precise documentation of coloration relative to a standard color range, such as that contained in the "Methuen Handbook of Colour", it is difficult, however, to make valid comparisons. Matsushima (1975) describes several species, such as *C. bisporum* Matsushima, *C. chlamydospora* Matsushima [as "*C. chlamydosporis*"], *C. colocasiae* Sawada, *C. laxicapitulatum* Matsushima and *C. porphorum* Matsushima as having colonies that are "brunneae", "brunneo-griseae", "fulvae", or "fuscae", but these terms are approximations and are too imprecise to be of use in making a detailed comparison. *Cladosporium breviramosum* differs in morphology from species known to have colonies in various shades of brown, as well as those that are olivaceous. The presence of opposite decussate, lateral, appressed or very slightly divergent, branches originating a short distance below the conidiophore apex in the manner of some species of *Paecilomyces* and *Penicillium* is infrequent in *Cladosporium*. Branching in most species of the genus occurs in the form of detachable ramiconidia. A species such as *C. orchidis* E.A. & M.B. Ellis, for example, which bears a conidial head superficially similar to that of *C. breviramosum*, branches by ramiconidia rather than non-detachable, true branches. Both *C. asterinae* Deighton and *C. musae* Deighton have branched conidiophores with some branches originating in a fashion similar to those of *C. breviramosum*. Branching in those two species is, however, somewhat irregular and branches are sometimes septate. Stover (1972) reported *C. musae* to usually have three or four terminal branches. Other branched species, such as *C. apicale* Berk., *C. gallicola* Sutton, and *C. gynoxidicola* Petrak, have widely divergent branches originating at separate levels along the upper third of their conidiophores. The conidia of *C. gynoxidicola* are more like those of species of *Phaeoramularia* Muntañola than *Cladosporium* but in its superficial habit on leaves and in possessing thick-walled, dark brown, branched conidiophores it is very different from that genus.

The verruculose to verrucose or tuberculate nature of the conidiophores of *C. breviramosum* is particularly distinctive. Some conidiophores are verruculose throughout most of their length, others are verruculose or verrucose predominantly towards their apices. In some instances, in conidiophores originating on the wallpaper substrate, the distal part becomes tuberculate. Such ornamentation is not unknown in the genus, however, but is much more pronounced in *C. breviramosum* than in other species. *Cladosporium resinae* (Lindau) de Vries [anamorph of *Amorphotheca resinae* Parbery] has conidiophores that are either smooth or bear irregularly scattered warts. Although the conidiophores of *C. herbarum* are smooth, the conidia are verruculose and those of *C. variabile* (Cooke) de Vries and *C. macrocarpum* are densely verrucose.

The penicillus-like conidial heads in *C. breviramosum* have a superficial appearance very much like those of species of *Paecilomyces* . Also, the conidial chains, apart from being branched, look similar to those of that genus although their ontogeny is entirely different. It resembles a number of other *Cladosporium* species in this regard including *C. avellaneum*, *C. elegans* Matsushima and *C. cerophilum* Matsushima.

FURTHER COMMENTS ON CLADOSPORIUM

Although over five hundred epithets have been published in the genus *Cladosporium* and a critical revision, based on type studies, is long overdue, authors have continued, during the last three decades, to describe many new species in it. It is well recognized that the task of determining the status of many of the older names is an onerous one and it is more than likely that difficulty will be experienced in typifying many of them. In addition, many species described in *Cladosporium* in the early literature are undoubtedly misplaced in it. Our current understanding of the genus stems in large part from the work of de Vries (1952) who described, noting their characteristics *in vitro*, *C. herbarum*, the type species, and eight others which he considered to be typical of the genus. In spite of uncertainty about the status of many binomials, addition of taxa to the genus has gone unabated in recent years. Between 1970 and 1986, to our knowledge, some forty-six species and one variety have been added to it. Of these, thirty-three were described as new. This activity has, at least in part, been undoubtedly stimulated by the work of de Vries and that of Ellis (1971, 1976), who added substantially to our knowledge of the genus by describing a total of forty-three species. Some of these were transferred into *Cladosporium* from such defunct genera as *Cladotrichum* Corda [= *Oedemium* Link, fide Hughes (1958)] and *Heterosporium* Klotzch [now considered a synonym of *Cladosporium*]. Other species treated included ones recognized from the time of the inception of the genus in 1815 to one described by B.C. Sutton in 1973. Some species are host-specific plant pathogens, many implicated in induction of leaf spots, others occupy peculiar ecological niches. Several, for example, *C. castellanii* Borelli & Marcano, *C. devriesii* Padhye & Ajello and *C. trichoides* Emmons var. *chlamydosporum* Kwon-Chung, have been associated with medical disorders of humans, whereas some, such as *C. chlamydospora* and *C. elegans*, are garden soil inhabitants. Several are hyperparasitic on other fungi, including rusts. A substantial number have been recorded from synthetic or partly artificial substrates. *Cladosporium leprosum* was described from a collection made on a painted surface of veneer/plywood in Alabama, *C. nigrellum* Ell. & Everh. is known from railroad ties (Morgan-Jones, 1977), and *C. brevicatenulatum* Rebrikova & Sizova from ancient cloth. A few species are ubiquitous. *Cladosporium resinae* has been reported from kerosene, soil, creosoted wood, resin, and face cream, while *C. herbarum* and *C. sphaerospermum* Penz. are known from foodstuffs, paint and textiles as well as dead, herbaceous and woody plants (Ellis, 1971). In view of the previously known occurrence of *Cladosporium* taxa in usual circumstances and on unnatural substrates, it was not surprising to come across two during the course of the present study. Their novelty and distinctive features were, however, unexpected.

Although unified by details of conidiogenesis and conidiophore, together with conidium morphology, the genus *Cladosporium*, as it now stands, is a somewhat heterogeneous taxon. The characteristics of possession of macronematous conidiophores, mostly integrated, sympodial, cicatrized, holoblastic conidiogenous cells, and catenate conidia bearing small but distinct, often protuberant scars, bring together a number of disparate elements. This is reflected by the fact that where teleomorph connections are known, some are totally unrelated. The teleomorph of *C. resinae*, *Amorphotheca resinae*, for example, is classified in the monogenic family Amorphothecaceae of the Eurotiales whereas *C. echinulatum* (Berk) de Vries and *C. iridis* (Fautr. & Roum.) de Vries, have teleomorphs, *M. dianthi* (Burt.) Jørstad and *M. macrospora* (Kleb.) Jørstad respectively, belonging to *Mycosphaerella* Johanson, a genus of the family Dothideaceae, order Dothideales. *Cladosporium herbarum*, the type species, also has a *Mycosphaerella* teleomorph, namely *M. tassiana* (de Not.) Johans (von Arx, 1950, 1983; Barr, 1958; Corlett, 1988). Barr (1958) considered the names *C. herbarum* and *C. macrocarpum* to be probably based on the same variable entity and Corlett (1988) reported an anamorph closer to *C. macrocarpum* than *C. herbarum* associated with one collection of

M. tassiana. It appears that *C. macrocarpum* is a form of *C. herbarum* having thicker-walled, more distinctly macronematous conidiophores, and larger, more verrucose conidia that bear up to three septa. *Cladosporium variabile* (Cooke) de Vries is also closely similar, being distinguished only by the presence of spirally coiled, aerial hyphae and pathogenicity to *Spinacia oleracea* L. Two species, *C. humile* J.J. Davis and *C. carpophilum* Thüm, have teleomorphs, *V. acerina* Plakidas and *V. carpophila* Fisher respectively, in *Venturia* Sacc., a member of the Venturiaceae, Pleosporales. The heterogeneous nature of the genus also accounts, at least to some degree, for the variety of habitats in which its members are found and growth capabilities *in vitro*. Those that are obligately pathogenic on higher plants, such as *C. caryigenum* (Ell. & Lang.) Gottwald, the causal organism of pecan scab, grow poorly on agar media (Gottwald, 1982) and are slow to sporulate, whereas, saprophytic species such as *C. cladosporioides* grow rapidly and sporulate abundantly in culture. Anomalies in anamorph/teleomorph connections, particularly where a teleomorph genus, such as *Venturia*, has anamorphs in more than one form-genus, well illustrate the unsatisfactory nature of some of the currently accepted taxonomy. There is little doubt, for example, that the *Cladosporium* anamorphs of *V. carpophila* and *V. acerina* have more natural affinity with *Fusicladium virescens* Bon., the anamorph of *Venturia pirina* Aderh. and type species of *Fusicladium* Bon., than they do with many of the saprophytic species of *Cladosporium* in spite of the fact that they resemble the latter in having catenate, cicatrized conidia. The dilemma that arises when attempting to classify some of these anamorphs is further illustrated by the nomenclatural history of *C. caryigenum* [syn. *Fusicladium effusum* Wint.], a species that has been removed from *Fusicladium* to *Cladosporium* and back again, only to end up recently once again in the latter (Demaree, 1928; Lentz, 1957; Gottwald, 1982). In morphology and growth pattern its conidiophores are similar to those considered typical of *Fusicladium*, and very like those of the *Fusicladium* state of *Apiosporina morbosa* (Schw.) Arx [Venturiaceae], the cause of black knot disease of *Prunus* spp., but it has catenate conidia which closely resemble those of *C. humile*. The fact that *Microcyclus ulei* (P. Henn.) Arx [Dothideaceae] has a *Fusicladium* anamorph also indicates the artificiality of these form-genera as presently conceived. Saprophytic forms, such as those described in this paper, and the species of *Cladosporium* that are obligate pathogens of higher plants are, clearly, phytogenetically unrelated. Their common denominator, presence of predominantly unicellular, cicatrized conidia borne in branched chains, reflects convergent evolution rather than true affinity. Even within those that are parasitic on higher plants, relatively clear-cut discontinuities are apparent. A series of species, most of which were at one time classified in *Heterosporium*, centered on the *Cladosporium* states of *Mycosphaerella dianthi* and *M. macrospora*, and including *C. albii-cepae* (Ranojevič) M.B. Ellis, *C. brassicae* (Ell. & Barth.) M.B. Ellis, *C. lacroixii* Desm., *C. magnusianum* (Jaap) M.B. Ellis, *C. ornithogali* (Klotzch) de Vries [lectotype species of *Heterosporium*], *C. phlei* (C.T. Gregory) de Vries and *C. polygonati* M.B. Ellis, form a natural group. Their broadly oblong, predominantly multiseptate, verruculose, mostly solitary conidia borne on geniculate, sympodial, frequently nodose conidiophores are distinctive. *Cladosporium herbarum*, *C. macrocarpum* and *C. variabile*, all three of which have verruculose to verrucose conidia, are allied to them. These are very different from the *Cladosporium* anamorphs of *Venturia* and similar species such as *C. buteicola* Cooke, *C. caryigena*, *C. cucumerinum* Ell. & Arth. and *C. spongiosum* Berk. & Curt, which have fusiform, smooth, mostly unicellular conidia. The genus has also contained several species with micronematous conidiophores and conidia which lack conidial scars. *Cladosporium bantianum* (Sacc.) Borelli, recently transferred to *Xylohypha*

(Fr.) Mason (McGinnis *et al.*, 1986), is one such example.

A critical revision of *Cladosporium* will necessitate not only determination of the status of the plethora of binomials contained in it but a reconsideration of the validity and usefulness of the presently accepted concept of the genus. Available knowledge indicates the presence of reasonably well-defined groups within it as currently circumscribed, namely; saprophytic forms, one of which is known to be the anamorph of a member of the Eurotiales, anamorphs of *Mycosphaerella* and similar forms, and anamorphs of *Venturia* and similar forms. The segregation of these into separate form-genera would result in a more natural classification but it remains to be seen whether or not all of the taxa in this complex can be satisfactorily assigned to one or other of these groups. Those that are likely to be problematic in this regard include some of the species bearing branched conidiophores alluded to earlier. Taxa such as *C. gallicola* and *C. asterinae*, which are hyperparasitic on other fungi, or those that occur superficially on leaves, such as *C. gynoxidicola*, do not fit well into any of the three categories but are closer to the saprophytic forms than to the pathogens. A species such as *C. uredinicola* Speg., which has pale, semi-macronematous, occasionally branched conidiophores, and is hyperparasitic on species of *Puccinia* Pers., grows well in culture and produces colonies on agar media very like those of saprophytic species (Morgan-Jones, unpublished data).

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CERIOSPOROPSIS CADUCA SP. NOV., A MARINE LIGNICOLOUS ASCOMYCOTINA FROM SUBMERGED WOOD.

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ABSTRACT

Ceriosporopsis caduca sp. nov. collected at Friday Harbour, San Juan Island, Washington State, U.S.A. and Doha beach, Kuwait is described, and compared with other species, in particular *C. cambrensis*, *C. halima* and *C. capillacea*. S.E.M. observations on spore appendage development is made.

INTRODUCTION

Zainal and Jones (1984) referred a fungus they collected on decayed planks of a stranded dhow in the intertidal zone at Doha, Kuwait to *Ceriosporopsis capillacea* Kohlm. Subsequent examination of the type and discussions with J. Kohlmeyer showed that this collection was misidentified and should be described as a new species. The fungus had previously been recorded in August-September 1981 at Friday Harbour, San Juan Island, U.S.A. The species description is based on the Friday Harbour collection, since this contained more material of the fungus.

MATERIALS AND METHODS

Driftwood entrapped amongst boulders was collected at various localities on San Juan Island, Washington State during August-September 1981 (Jones, 1985) and wood from the intertidal zone was collected at Doha port, Kuwait, January-February, 1983 (Zainal and Jones, 1984). The wood was subsequently incubated for several months and examined periodically for fruiting bodies (Jones, 1971). Scanning electron microscope techniques are as described by Moss and Jones (1977).

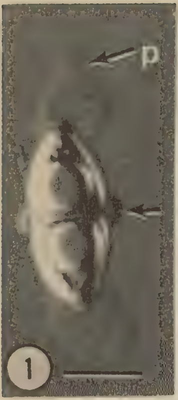
TAXONOMIC PART

Ceriosporopsis caduca sp. nov. (Figs. 1-18)

Ascocarpi 800-900μm alti, 900-1100μm diametro, ellipsoidei-subglobosi, immersi, ostiolati, papillati, coriacei, brunneoli ad brunnei. Peridium 2-stratum, 35μm crassum. Collum 150-1000μmlongum, 85-95μm diametro, cylindricum, periphysatum. Pseudoparenchyma leptodermum. Asci 97.0-135.0 x 20-25μm, octospori, clavati, pedunculati, unitunicati, leptodermi, sine apparato apicali, maturitate deliquescentes, ad basim ascocarpi orientes. Ascosporae (10-) 21.0-34.0 x 10.0-17.0μm (mediet. 27.0 x 12.0μm), ellipsoideae, uniseptatae, hyalinae, appendicibus polaribus in utroque extremo, et appendice annulari circum septum centrale. Appendices polares ex parietis sporae orientes, 10.0-54.0 x 3.0-5.0μm (mediet. 25.0 x 3.0μm), et cinctae fabrica sacciformi in aqua cadenti. Habitat: in ligno.

Ascocarps 800-900μm high, 900-1100μm in diameter, ellipsoid to subglobose, immersed, ostiolate, papillate, coriaceous, light brown to brown. Peridium 35μm thick, two-layered. Neck 150-1000μm long, 85-95μm in diameter, cylindrical, centrally inserted, periphysate. Pseudoparenchyma thin-walled. Asci 97.0-135.0 x 20.0-25.0μm, eight spored, clavate, pedunculate, unitunicate, thin-walled, no apical apparatus, deliquescing at maturity, born at the base of the ascocarp. Ascospores (10-) 21.0-34.0μm long x 10.0-17.0μm (average 27.0 x 12.0μm), (excluding appendages), ellipsoidal, one septate, hyaline with polar appendages at each end and an annulus-like appendage around the central septum 5-7μm thick. Polar appendages arising as outgrowths of the spore wall, 10.0-54.0 x 3.0-5.0μm (average 25.0 x 3.0μm) and surrounded by a sac-like structure which is shed when mounted in water.

Figs. 1-10. *Ceriosporopsis caduca*. All interference light micrographs. 1-4. Ascospores with coiled polar appendages (arrowed p) and equatorial appendages (arrowed). 5-8. Ascospores with uncoiled polar appendages (arrowed p) with the outer sac-like sheath (arrowed 0) and central part (arrowed c). Equatorial appendages arrowed. 9,10. Ascospores with polar (central portion arrowed c), outer sheath like part (arrowed 0), equatorial appendages (arrowed) and discarded outer sheath of the appendage (arrowed do). Bar lines: 10μm.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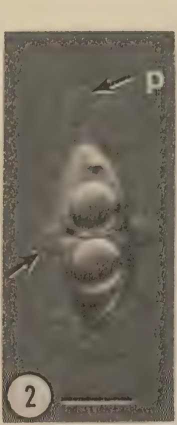
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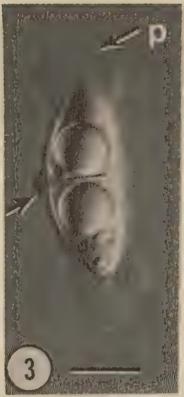
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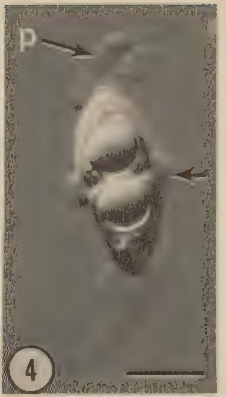
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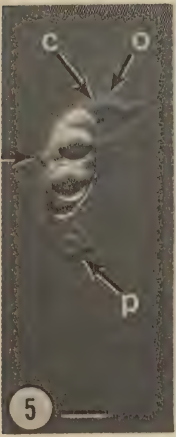
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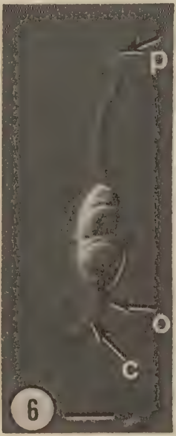
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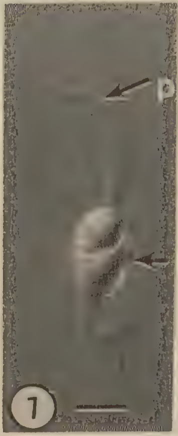
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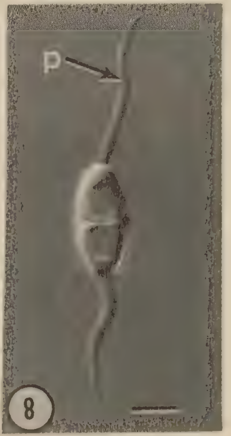
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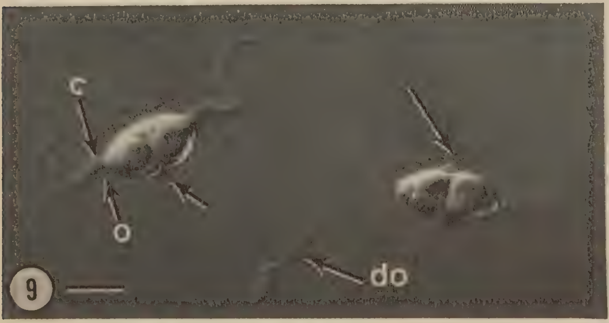
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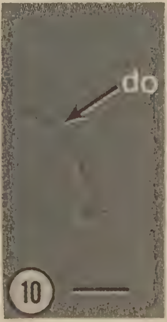
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Substrates: Driftwood (*Pinus* sp.)

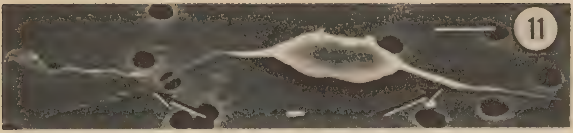
Holotype: Slides 1-11 and dried material I.M.I. 322552.

Isotype: Dried material on driftwood, Friday Harbour, Washington State, September 1981, deposited at the Herbarium, Portsmouth Polytechnic.

Etymology: From the Latin *caducus* = falling with reference to the shedding of the outer sheath surrounding the polar appendages.

Johnson, Jones and Moss (1987) in their review of the genus *Ceriosporopsis* accept 3 species (*C. halima* Linder, *C. cambrensis* Wilson and *C. tubulifera* (Kohlm.) Kirk, while they suggest that *C. capillacea* and *C. circumvestita* Kohlm. & Kohlm. be re-examined at the transmission electron microscope level for spore appendage development and ontogeny. Koch and Jones (1986) have described *C. sundica* Koch & Jones from collections made in Denmark and pointed to the uncertain position of *C. barbata* Höhnk, a species of which there is no original material left. Although three species are accepted on ultrastructure features of the ascospores and appendages, there is considerable difference in spore ontogeny between *C. halima* and *C. tubulifera*. The former has polar appendages that arise from the spore wall, and are surrounded by an exosporium which breaks up at maturity. In *C. tubulifera* the exosporium is persistent and forms an end chamber within which the polar appendage develops. The appendage does not arise from the spore wall. Johnson *et al.* (1987) retain *C. tubulifera* within the genus until other species are examined and to enable an evaluation of the degree of variation in spore ontogeny to be undertaken. *C. tubulifera* also differs from *C. halima* in having equatorial appendages. *C. sundica* and *C. caduca* appear to have appendages that arise from the spore wall (Figs. 17, 18) and thus agree with that of the type species *C. halima*. However, this aspect needs to be confirmed at the transmission electron microscope level.

Figs. 11-18. *Ceriosporopsis caduca*. All scanning electron micrographs. 11. Ascospore with long polar appendages (arrowed). 12-14, 16. Outer sac-like sheath of the polar appendages (arrowed) which separates from the inner part (arrowed 0). 15, 17, 18. Strap-like polar appendage once the outer sheath has been discarded. Bar lines: 11-17 = 10μm, 18 = 2.5μm.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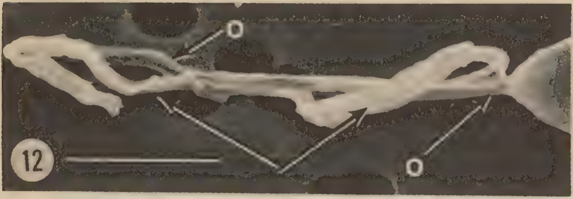
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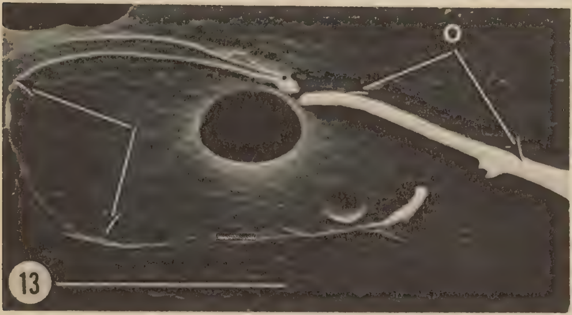
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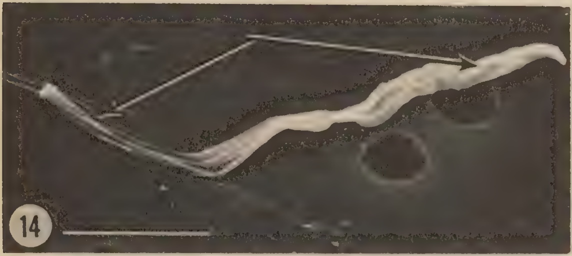
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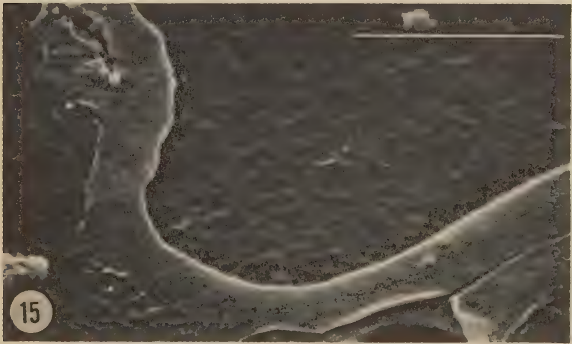
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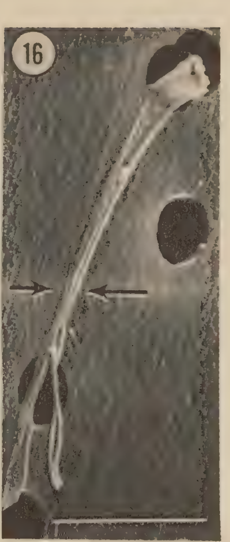
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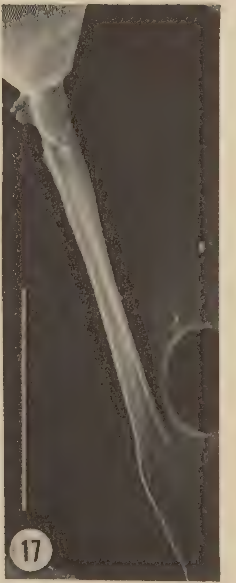
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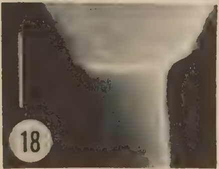
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Polar appendages in *C. capillacea* are hollow tubes but their origin is unknown. For example, are they homologous with the end chambers of *C. tubulifera? C. circumvestita*, unlike the type species (but similar to *C. tubulifera*), has both polar and equatorial appendages. However, unlike *C. tubulifera*, no mucilage is extruded from the polar appendages and both polar and equatorial appendages are persistent in *C. circumvestita*.

As can be seen from the above discussion *C. caduca* has characteristics in common with *C. halima* and *C. tubulifera*. Spore appendages that arise from the spore wall are reminiscent of *C. halima* but is the shed sac-like sheath (Figs. 9, 10, 12-14, 16) homologous with the exosporial layer of *C. halima*? *C. tubulifera* and *C. caduca* both have polar and equatorial appendages (Figs. 1-8), but the polar appendages develop in quite different ways. Many ontogenetic features need to be examined at the transmission electron microscope level before the taxonomic position of all these species can be resolved. Much depends on the availability of fresh material for examining developmental and ontogenetic processes.

Spore dimensions in *C. caduca* (21.0-(27.0)-34.0 x 10.0-(12.0)-17.0μm) most closely resemble those of *C. cambrensis* (29.0-31.5 x 10.5-14.5μm). However, the two species differ in the colour of the perithecia (black in *C. cambrensis*, pale brown in *C. caduca*), while *C. caduca* has both polar and equatorial appendages, the latter absent in *C. cambrensis*.

In *C. caduca* the polar appendage is composed of two components: an outer tube-like persistent component which separates at its point of attachment (Figs. 12, 17) to the spore to reveal an inner mucilaginous or gelatinous appendage which appears strap-like (Figs. 15, 17). Discarded tubes are frequently found on the slides or membranes (when prepared for S.E.M.)(Figs. 9, 10, 14, 16). The appendage proper is sticky and attaches the spore to surfaces (Fig. 15). This species differs from *C. capillacea* in the strap-like appearance of the polar appendage. In *C. capillacea* the polar appendage is tube-like with oil globules from the cells "passing" into the appendages (Kohlmeyer, 1981).

The main collection was from driftwood collected at Friday Harbour (temperate water), while a collection was also made from Doha, Kuwait.

KEY TO SPECIES OF CERIOSPOROPSIS LINDER

1. Polar appendages only	2
1. Polar and equatorial appendages	5
2. Appendages, a hollow tube	*C. capillacea* Kohlm.
2. Appendages, not a hollow tube	3
3. Ascospores longer than 28μm	*C. cambrensis* Wilson
3. Ascospores shorter than 28μm	4
4. Exosporic sheath, wide, constricted at the septum	*C. sundica* Koch & Jones
4. Exosporic sheath, narrow, not constricted at the septum	*C. barbata* Höhnk
5. Mucilage released from polar appendage	*C. tubulifera* (Kohlm.) Kirk
5. No mucilage released from polar appendage	6
6. Polar appendage persistent, equatorial appendage lobed	*C. circumvestita* (Kohlm.) Kohlm.
6. Sheath surrounding polar appendage shed, equatorial appendage not lobed	*C. caduca* Jones & Zainal

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We thank the following for their help: Messrs. G. Bremer, R. Healey and C. Derrick for photographic assistance; Dr. J. Koch for reviewing the manuscript; and Professor J. Kohlmeyer for taxonomic assistance and for allowing us to examine type material. E.B. Gareth Jones would like to thank the Director, Dr. Dennis Willows, and staff of the Friday Harbour Marine Laboratory, San Juan Island (University of Seattle); the Royal Society for the award of a travel grant from the Marshall and Orr Bequest for financing the U.S.A. visit; and the Research Committee of Kuwait University for funds to visit Kuwait.

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MYCOTAXON

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TAXONOMICAL STUDIES ON USTILAGINALES. II.

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ABSTRACT

Three new species of Ustilaginales are described: Anthracoidea kukkonenii Vánky on Carex distachya, Doassansia sparganii Vánky on Sparganium erectum, and Thecaphora oberwinkleri Vánky on Androsace fedtschenkoi.

In the course of my taxonomical investigations on Ustilaginales, several specimens could not be identified with any earlier known species and therefore they are proposed here as new species. These are: Anthracoidea kukkonenii Vánky, in the ovaries of Carex distachya Desf. from Algeria, Doassansia sparganii Vánky, in the leaves of Sparganium erectum L. from Czechoslovakia, and Thecaphora oberwinkleri Vánky, in the seeds of Androsace fedtschenkoi Ovcz. from China.

Anthracoidea kukkonenii Vánky, sp. nov.

Typus in matrice Carex distachya Desf. (subgen. Indocarex), Algeria, Castiglione, 29.III.1925, leg. H. Humbert (Herb. R. Maire 8646, MPU!).

Sori in ovariis dispersis corpuscula ovoidea, dura, cca. 4 mm longa formantes, in statu juvenili membrana argentea fungo orta obtegenti sed serius dissoluta et massam nigram agglutinatamque sporarum monstranti. Sporae forma et magnitudine variae, e latere subcirculares, ovoideae usque ad irregulariter rotundato-polyangulares, 13–22 x 14–24 µm, e latere compressae (12–15 µm crassae), atro-rufobrunneae, pariete inaequaliter incrassato, 1,5–4 µm crasso, in angulis crassissimo, in LM leniter et dense verruculoso (propterea extrema linea sporarum undulata vel subtiliter serrulata), gibberis 1–3 vix conspicuis usque ad bene evolutis, deinde nonnunquam areis refractivis ad partem crassissimam parietis, deique super polos pileis tenuibus instructo. Superficies sporarum in SEM verrucis dense dispositis, humilibus, rotundatis et ad polos nonnunquam lineamentis irregulariter confluentibus, verrucosis.

Ab Anthracoidea caricis (Pers.) Bref. s. str. imprimis sporis forma magis regularibus, obscurioribus et pariete earum crassiore differt.

Sori (Fig. 1) in scattered ovaries forming ovoid, hard bodies, c. 4 mm long, when young covered by a thin, silvery fungal membrane which flakes away exposing the black, agglutinated spore mass. Spores (Fig. 2) variable in form and size, in plan view subcircular, ovoid to rounded polyangularly irregular, 13–22 x 14–24 µm, flattened (12–15 µm thick), dark reddish-brown; wall of uneven thickness, 1.5–4 µm wide, thickest at the angles, in LM finely and densely verruculose causing the spore profile to appear wavy or finely serratulate, 1–3

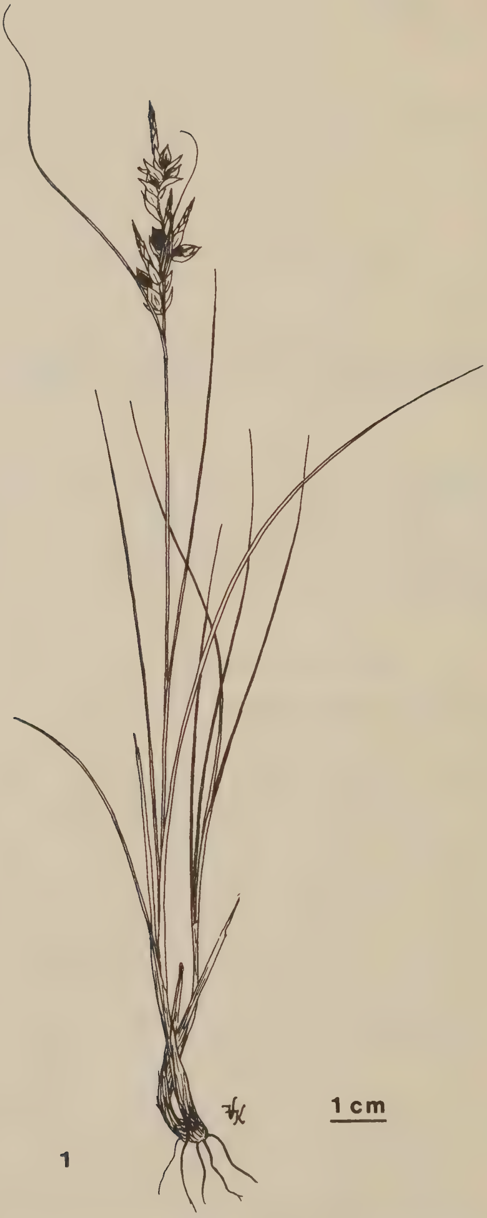

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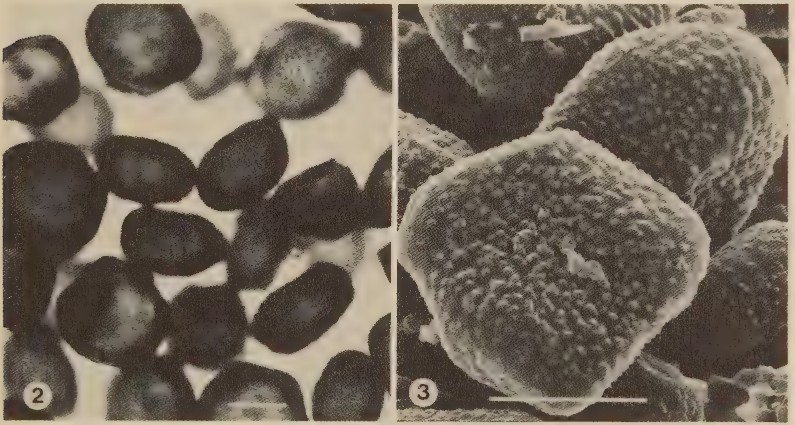
Fig. 1. Anthracoidea kukkonenii on Carex distachya (Type).
Sori in scattered ovaries.

hardly visible to well-developed internal swellings present and sometimes light-refractive spots on the thickest area, and also thin, hyaline caps on the polar regions. Surface in SEM (Fig. 3) provided with densely situated, low, rounded warts, and sometimes with an irregularly confluent verruculose pattern on the polar regions as a result of the dried hyaline caps.

Differs from Anthracoidea caricis (Pers.) Bref. s. str. especially in its more regular, darker spores possessing thicker walls, and in parasitising a member of the subgenus Indocarex.

There is an additional report (Lagerheim, 1889:127) of an Anthracoidea species (under the name Ustilago caricis Fuckel) on Carex longiseta Brot. (= C. distachya), from Serra d'Arrabida, near Convento da Serra, IV.1848, F. Welwitsch, which I at first suspected might refer to this species. However, the examination of the specimen preserved in Lisboa (LISU) revealed the host plant to be Carex depressa Link or C. halleriana Asso (rev. R. Berndt), and its parasite to be a different Anthracoidea species. Another collection in Maire's herbarium (MPU), labelled as Cintractia caries on Carex distachya, from Algeria (Alger, 20.III.1942, J. Feldmann), similarly does not belong to A. kukkonenii; the host plant not being C. distachya.

This species is dedicated to Dr. Ilkka Kukkonen (Botanical Museum, University of Helsinki, Finland) the reviver and reviewer of the genus Anthracoidea.



Figs 2–3. Spores of Anthracoidea kukkonenii (Type) in LM and in SEM. (Bars = 10 µm).

In several herbaria there are preserved samples of "Entyloma Typhacearum Niessl" (on one label even "f. Sparganii ramosi"), "An Sparganium, Brünn, v. Niessl", with Niessl's handwritten labels. The name is apparently a herbarium name. The examination of the leaf-fragments of Sparganium erectum L. (= S. ramosum Huds.; verif. C.D.K. Cook) showed that they contain spores of Physoderma sparganii-ramosi (Büsgen) Schröter and, in addition, spore balls of an undescribed Doassansia species.

Doassansia sparganii Vánky, sp. nov.

Typus in matrice Sparganium erectum L. (= S. ramosum Huds.), una cum: Physoderma sparganii-ramosi (Büsgen) Schröter, Cechoslovacia, Moravia, Brno (olim Brünn), leg. G. Niessl von Mayendorf. Holotypus in Herbario Ustil. Vánky (HUV 7411), isotypi in BP, BPI, K, M. (Unfortunately, there is no material of this fungus preserved in BRNM, PR and PRC; K. Sutory, in litt.).

Sori foliicolae, inconspicui, in speciminibus vetustis a textis foliorum sanis non distincti, glomerulos sporarum singulos vel aggregatos continentes, in textis matricis immissi, post dissolutionem foliorum tantum visibiles. Glomeruli sporarum globosi, ovoidei, elongati vel parum irregulares, 160–200 x 160–320 µm, permanentes, pallide brunnei, e massa centrali sporarum permultarum (pluries centum?), a stratis irregularibus 2–5 cellularum sterilium circumdata compositi. Sporae ellipsoideae, elongatae vel plerumque irregulariter rotundato-polyangulares, 6,5–10,5 x 9–14 µm, sat dense collocatae, subhyalinae usque ad pallide flavae, pariete tenui (cca. 0,5 µm crasso), leves. Cellulae steriles dense compactae, rotundatae usque ad elongato-irregulares, saepe parum lobatae, sporis majores (9–14 x 12–24 µm), pallide flavobrunneae, inanes, pariete levi, 0,5–1(–1,5) µm crasso.

Sori (Fig. 4) in the leaves, inconspicuous, in old material indistinguishable from the healthy tissues, containing solitary or grouped spore balls embedded in the host tissue, visible only on dissection of the leaves. Spore balls (Fig. 5) globose, ovoid, elongate or slightly irregular, 160–200 x 160–320 µm, permanent, light brown, composed of a central mass of numerous (hundred?) spores surrounded by 2–5 irregular layers of sterile cells. Spores ellipsoid, elongate or most frequently rounded polyangularly irregular, 6.5–10.5 x 9–14 µm, rather densely situated, subhyaline to pale yellow, thin-walled (c. 0.5 µm), smooth. Sterile cells closely compacted, rounded- to elongated-irregular, often somewhat lobed, larger than the spores (9–14 x 12–24 µm), light yellowish-brown, empty, with smooth, 0.5–1(–1.5) µm thick wall.

Another spore-ball-forming smut in the leaves of Sparganium erectum is Nannfeldtiomyces sparganii (Lgh.) Vánky, which unlike Doassansia sparganii has loose, readily disintegrating spore balls composed of spores and a network of thin, branched mycelia (comp. also Vánky 1981).

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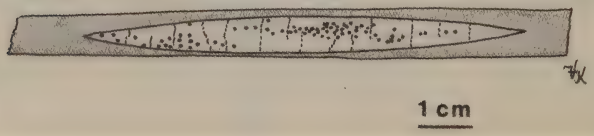

Fig. 4. Doassansia sparganii on Sparganium erectum (Type).
Sori with spore balls embedded in the leaf tissue.

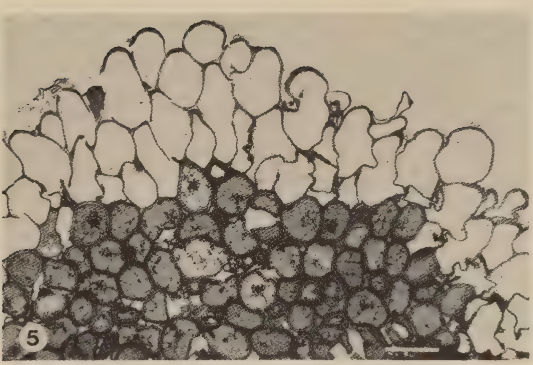

Fig. 5. Part of a spore ball of Doassansia sparganii (Type) composed of a central mass of spores surrounded by sterile cells in several, irregular layers (Embedded in Spurr's plastic, sectioned, and stained with crystal-violet; Bar = 10 µm).

During the revision of herbarium specimens from Leningrad - Pushkin (LEP), I found a collection of Androsace fedtschenkoi parasitised by an undescribed Thecaphora species:

Thecaphora oberwinkleri Vánky, sp. nov.

Typus in matrice Androsace fedtschenkoi Ovcz., Sina, Dzhagir, Otu-Serdzhal, 2.VII.1897, leg. E.M. Shumakov (LEP!).

Sori corrumpantes semina, refercientes capsulas matricis massa glomerulorum brunnea, glomeruloso-pulverea, evacuanda per apices capsularum in statu dehiscendi. Glomeruli sporarum globosi, subglobosi, ovoidei, raro usque irregulariter elongati, 28–56 x 28–77 µm, mediocriter aurantiaco-brunnei, e sporis multis (10–)20–cca.100, firmiter connectis compositi. Sporae forma et magnitudine variae, principaliter formam pyramidi rotundati imitantes: basis earum versus superficiem apex vero versus centrum glomeruli spectans, altitudine 10–16(–20) µm. Basis sporarum extrorsa irregulariter rotundato-polyangularis, 5–12 x 6–16 µm, papillis remote usque densiuscule sparsis, crassis, irregularibus, usque ad 3 µm altis ornata. Sporae singulares, sub SEM per cristam levem elevatam unitae. Paries contiguus sporarum tenuis (cca. 0,5 µm), levis.

A Thecaphora androsacina Vánky, in Androsace maxima L., imprimis glomerulis polysporis sporarum firmiter unitarum, et cristis inter sporis in superficie glomerulorum sub SEM visibilibus distincta, in comparatione sporarum minorum (16–35 x 20–52 µm), facile separabilium, deinde glomerulorum 2–15(–25 ?)-sporarum, atque inopiae cristarum inter sporas Thecaphora androsacinae.

Sori (Fig. 6) destroy the seeds, filling the capsules with a brown, granular-dusty mass of spore balls which become scattered when the capsules open at their apices. Spore balls (Fig. 7) globose, subglobose, ovoid to rarely irregularly elongated, 28–56 x 28–77 µm, medium orange-brown, composed of numerous, (10–)20–100?, firmly united spores. Spores (Fig. 7) variable in form and size, shape basically rounded pyramidal, oriented with base on the surface and top toward the centre of the spore ball, height 10–16(–20) µm. The free surfaces of the spores are irregularly rounded-polyangular, 5–12 x 6–16 µm and provided with sparsely to moderately densely situated, coarse, irregular papillae, up to 3 µm high. In SEM (Fig. 8) the spores are united by elevated, smooth ridges. The contiguous walls of the spores are thin (c. 0.5 µm), smooth. Type on Androsace fedtschenkoi Ovcz., China, Dzhagir, Otu-Serdzhal, 2.VII.1897, coll. E.M. Shumakov (LEP).

Differs from Thecaphora androsacina Vánky, on Androsace maxima L., especially by its large, many-spored balls composed of firmly united spores, and by the presence of ridges between the spores on the surface of spore balls seen in SEM, as compared with the smaller (16–35 x 20–52 µm), readily separating spore balls composed of 2–15(–25?) spores in T. androsacina, in which ridges between the spores are also lacking (Figs. 9, 10; comp. also Vánky, 1982).

This species is named in honour of the excellent botanist and fine human being: Professor Franz Oberwinkler (University of Tübingen, W. Germany).

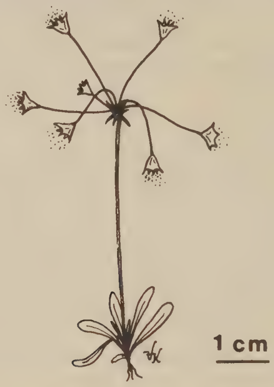

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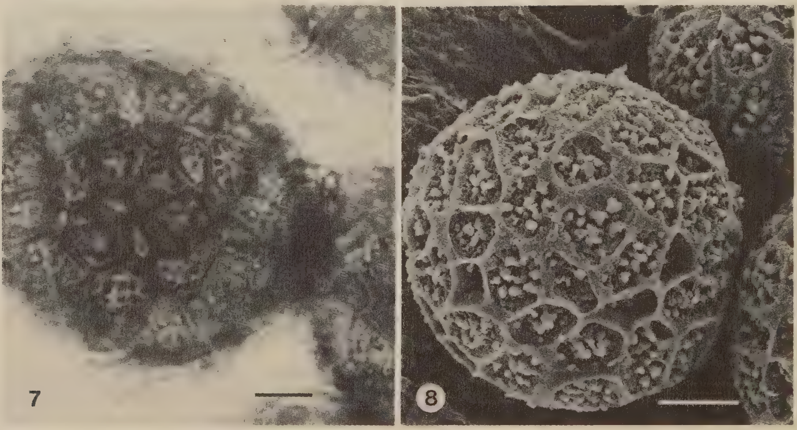
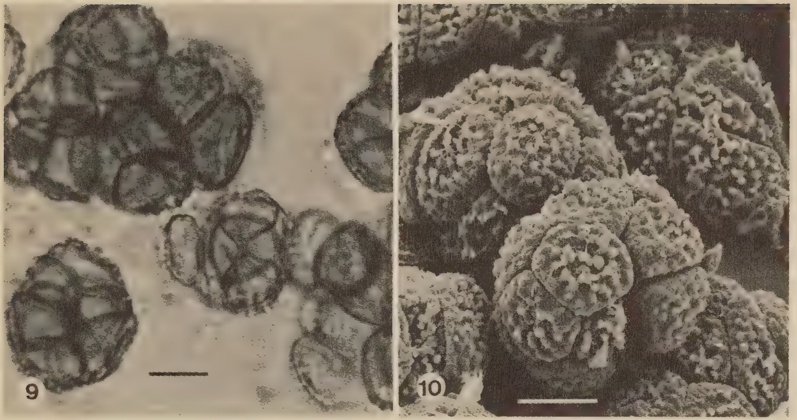
Fig. 6. Thecaphora oberwinkleri on Androsace fedtschenkoi (Type). Sori in the capsules destroying the seeds.



Figs. 7–8. Spore balls and spores of Thecaphora oberwinkleri in LM and in SEM. (Bars = 10 µm).



Figs. 9–10. Spore balls and spores of Thecaphora androsacina Vánky on Androsace maxima L. (USSR, Saratov, 1.VI.1922, A. Doroschenko) in LM and in SEM. (Bars = 10 µm).

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STUDIES IN THE GENUS PHOMA. XII. CONCERNING PHOMA DESTRUCTIVA, A SECOND SPECIES IMPLICATED AS A PATHOGEN OF TOMATO.

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ABSTRACT

Phoma destructiva Plowright, the causal organism of tomato fruit rot, is described and illustrated. Its cultural characteristics and the anatomy of its pycnidial wall are documented. Differences between it and *Phoma lycopersici* Cooke, the anamorph of *Didymella lycopersici* Klebahn, are noted.

INTRODUCTION

In the immediately preceding paper in this series, in which *Phoma lycopersici* was redescribed, we alluded to the fact that it resembles *Phoma destructiva*, another species commonly occurring on tomato [*Lycopersicon esculentum* Mill.]. *Phoma destructiva* is, like *P. lycopersici*, implicated in tomato fruit rot, but apparently has a wider host range. As indicated previously (Morgan-Jones and Burch, 1988), however, the literature on the subject of occurrence of particular *Phoma* species, including the above mentioned two and *Phoma exigua* Desm., on members of the Solanaceae is replete with questionable information, contradictions, and doubtful application of binomials. It is therefore next to impossible to determine with certainty many host records and even, in some instances, the association of individual taxa with specific disease syndromes.

Phoma destructiva was originally described by Plowright (1881) as the cause of a black spot upon the crown of tomato fruit. In the same year Spegazzini (1881) described a fungus, *Phyllosticta hortorum* Speg. [≡ *Ascochyta hortorum* (Speg.) C.O. Sm.], found as a pathogen on leaves of eggplant and, almost twenty years later, Ellis and Everhart (1900) stated that this was common on tomato leaves.

The occurrence and characteristics of *P. destructiva* were the subject of a detailed study by Jamieson (1915) who reported the fungus to cause a fruit rot of tomatoes originating in Cuba and several states in the U.S., including Florida. Most infected tomatoes had conspicuous dark lesions on the side and near the stem end. Inoculation experiments showed it to be an active wound pathogen of green and ripe tomatoes and also to cause leaf spotting of eggplant [*Solanum melongena* L.], tomato and potato [*Solanum tuberosum* L.] plants under highly artificial conditions. In the case of eggplant, spotting was induced only when

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plants were kept under bell jars for extended periods. In a discussion on the taxonomy of the causal organism, Jamieson expressed doubt that the fungus reported on tomato leaves by Ellis and Everhart was *Phyllosticta hortorum*. That may or may not have been so since *P. hortorum* is now recognized as being a facultative synonym of *Phoma exigua* var. *exigua*, an ubiquitous fungus often associated with leafspots and lesions on stems and roots of a variety of host plants (Boerema and Höweler, 1967). The long-standing uncertainty that has existed about identity of *Phoma*-complex fungi encountered on solanaceous hosts is illustrated by the fact that Harter (1914) concluded that *P. hortorum* had not been found in the U.S.A. Similarly, when Marchal (1900) recognized a *Phoma* as the cause of a new disease of greenhouse-grown tomatoes in Europe, he chose not to apply a binomial to it. Jamieson also noted that *Phoma lycopersici* Cooke, described from stems of tomato (Cooke, 1885), had conidia twice the average size of those of *P. destructiva*. Following examination of type material of *Phyllosticta lycopersici* Peck and comparison with her own isolates of *P. destructiva*, she correctly determined the two to be conspecific. The latter name has date priority. Apart from the description of the conidia as being produced on "unbranched filiform basidia", the emended account of the species given by Jamieson is accurate and, for its time, reasonably detailed.

A succession of authors, including Brooks and Searle (1921), Klebahn (1921), Wollenweber and Hochapfel (1936), Dennis (1946), Knight (1960), Laundon (1971), and Boerema and Dorenbosch (1973), all of whom studied the two species in pure culture, was able to distinguish *P. destructiva* and *P. lycopersici*. Grove (1935), however, considered the two to be identical. Holliday and Punithalingam (1970), incidentally, incorrectly stated that Brooks and Searle (1921) considered *Phoma destructiva* to be synonymous with *Diplodina lycopersici* Hollós [= *P. lycopersici*]. Both Brooks and Searle (1921), who examined four isolates of *P. destructiva*, including one originating in the U.S.A. obtained from Dr. C.L. Shear in 1916 [referred to as an "authentic culture" because it was, presumably, one of C.O. Jamieson's], and Wollenweber and Hochapfel (1936), who isolated the fungus once from potato, gave it the authority '(Plowr.) Jamieson' erroneously. This was probably because of Jamieson's emendation of the original description by Plowright. The practice of giving the binomial this authority continued for some years thereafter; e.g. as by Obrero *et al*. (1968). Petrak (1921) transferred *P. destructiva* into *Diplodina* Westd., as *D. destructiva* (Plowr.) Petrak, but it is evident that the name was misapplied by him to *P. lycopersici* (Boerema and Dorenbosch, 1973).

In the various reasonably reliable accounts of *P. destructiva* published to date, there is general consensus that the fungus usually produces pycnidia readily *in vitro*, has dark colonies when mature with comparatively little aerial mycelium or a thin, even mat of grayish mycelium of various shades, and produces small, unicellular, ellipsoid conidia. There are, however, discrepancies among descriptions. Brooks and Searle (1921) described their isolates, including the one obtained from the U.S.A. [designated forms A, B, H, and Q; cf. our previous discussion (Morgan-Jones and Burch, 1988)], as having fairly plentiful white to gray aerial mycelium when grown on Dox's medium amended with cane sugar. They noted, however, that the quantity of mycelium produced varied greatly on different media. Unfortunately, their accounts of individual isolates differ in degree of detail with only occasional mention made of characteristics on media other than Dox's. Their forms A and B were said, when grown on potato agar, to have little aerial mycelium. Form B, when grown on this medium, was described as having largely submerged, dark mycelium. No mention was made of the characteristics of their forms H and Q under these nutritional conditions. Pycnidial production was reported to vary between the isolates, with form Q forming few pycnidia on all media.

Grimes *et al.* (1932) applied the name *P. destructiva* to an isolate obtained from butter and concluded that it and *Phyllosticta hedericola* Dur. & Mont. [≡ *Phoma hedericola* (Dur. & Mont.) Boerema] were identical. The fungus was described as "rather fluffy", with grey aerial hyphae, when grown on potato agar and its colony margin as lobed. Pycnidia were said to be few or absent. As a result of inoculation experiments, it was concluded that *P. destructiva* was parasitic not only on potato but also on ivy [*Hedera helix* L.]. As Boerema and Dorenbosch (1973) have pointed out, however, it is probable that these authors had a fungus other than *P. destructiva* under study. In the same publication, the name *Phoma hibernica* Grimes, O'Connor & Cummins was proposed for other isolates obtained from butter, as well as from cream, milk and water. Those isolates are now considered to have been *P. herbarum* Westd. (Boerema, 1964).

During the past thirty years, a number of further attempts have been made to resolve the question of the distinction between *P. destructiva* and *P. lycopersici*, particularly as it relates to plant disease induction and symptom development. Some of the literature on the subject produced during this period is, however, fraught with the same kinds of interpretative difficulties as are experienced when reviewing earlier publications because of some uncertainty as to which entities individual researchers had under study in particular instances.

Phoma destructiva has been considered a minor pathogen of tomato in Europe and elsewhere, causing black rot on green and mature fruit by such authors as Govi (1953), Gunther and Grümmer (1958), and Grover (1965). Some researchers, particularly Ceci (1955) in Italy, Gally and Tokeshi (1961) in Brazil, Obrero *et al.* (1968) in Hawaii, and Fournet (1971) in Guadaloupe, mention foliar lesions occurring independently or in association with fruit rot. Ceci (1955) considered that, in the absence of a teleomorph, the type of symptom induced can be used as a means to distinguish between *P. destructiva* and *P. lycopersici*; the former attacks leaves and fruit, while the latter causes stem lesions. Dennis (1946) had, however, noted that rotting of tomato fruit and production of lesions when inoculated to stems are not sufficient criteria for identification of *P. lycopersici*. Knight (1960) studied a series of *Phoma* isolates from lesions on tomato stems and fruit and determined that they could be grouped into those that were pathogenic to stems and fruit and those that were pathogenic to fruit only. Members of the former group produced some bicellular conidia and were considered to be *P. lycopersici*, while those in the second group conformed to *P. destructiva*. Fournet (1971) stated that a distinction made on the basis of *P. lycopersici* causing stem canker and rot was still controversial because of research reported by Jones *et al.* (1966) and Truszkowska (1967). Jones *et al.* stated that *P. destructiva* caused considerable plant loss by girdling of tomato transplant stems during a *Fusarium* wilt test. They referred to a *Phoma* stem canker of tomato as being caused by *P. destructiva*. Regrettably, there is no means of knowing what species they were actually dealing with, although by inference, given the experience of others, it seems likely that they were using a wrong name and had *P. lycopersici* rather than *P. destructiva*.

The most recent information on the cultural characteristics of *P. destructiva* is that of Aulakh *et al.* (1969), Laundon (1971), Boerema and Dorenbosch (1973) and Sutton (1980). Aulakh *et al.* (1969) attempted to provide an account of the variability and host range of *P. destructiva* but, as suggested by Boerema and Dorenbosch (1973), whose views were endorsed by Morgan-Jones and Burch (1988), it seems probable that the authors were describing more than one entity. Isolates from *Phoma*-infected tomato fruits were categorized as three distinct strains on the basis of cultural characteristics. No account was given of morphology beyond brief comments on colony color and appearance, together with a statement that,in size and shape, pycnidia and conidia of all three were the same as given for *P. destructiva* in the literature. One type was said to produce ochraceous mycelium and a reddish tinge to the substrate, another was described as being brownish-black and fluffy with the medium becoming dark, while the third was noted to produce a whitish, cottony colony. In inoculation experiments the three types, referred to as "distinct biological forms" of *P. destructiva*, varied in their capacity to infect a range of tomato cultivars and to colonize leaves and/or fruits. Differences in virulence were also observed. In addition, varying results were obtained when one isolate was artificially inoculated onto eight different hosts. Fruits of *Capsicum frutescens* L., *Datura alba* Nees, and *Withania somnifera* Dun. became infected and both fruits and leaves of *Solanum melongena* were found to be susceptible. Because of the somewhat uncritical approach to the matter of species identity, and bearing in mind that both *P. exigua* and *P. lycopersici* have also been implicated in tomato fruit rot, it is difficult to lend credence to some of the conclusions reached by Aulakh and coworkers.

Laundon (1971) reported isolating *P. destructiva* regularly from rots of tomato fruit imported into New Zealand, but it was not encountered in material originating in that country. Material of tomato stem rot from New Zealand yielded *P. lycopersici*, and *P. exigua* was isolated from both stem and fruit rots. A previous record of *P. destructiva* occurring in New Zealand (Atkinson *et al.*, 1949) should, according to Laundon, be treated with caution. A brief but useful comparison of the distinguishing features of colonies of *P. destructiva*, *P. exigua*, and *P. lycopersici* was provided.

Boerema and Dorenbosch (1973), in a review of *Phoma* and *Ascochyta* species described by Wollenweber and Hochapfel (1936) in a study of fruit-rotting, provided a brief description of *P. destructiva* on oatmeal agar. On this medium, the fungus was described as producing colonies with a greenish tinge to the mycelial mat and abundant pycnidia. Fournet (1971) also reported production of greenish-black pigment and numerous pycnidia on oatmeal agar. Sutton (1980), following a short account of the characteristics of *P. lycopersici*, stated that the distinction between it and *P. destructiva* is marginal, the latter differing in producing smaller, aseptate conidia and colonies in which aerial mycelium is usually lacking. *Phoma lycopersici* was also said to differ from *P. destructiva* by limited pycnidial production in colonies having well-developed aerial mycelium and stilboid aggregations of hyphae in the former.

In our ongoing effort to provide modern, comprehensive descriptions of *Phoma* species, and thereby facilitate correct application of binomials, we offer herein a treatment of *P. destructiva*. Its salient features are documented although we cannot, until more isolates become available for examination, provide a full account of cultural variation.

TAXONOMIC PART

Phoma destructiva Plowr., *Gard. Chron.* 16: 621, 1881 (Plates 1 & 2, Figure 1).

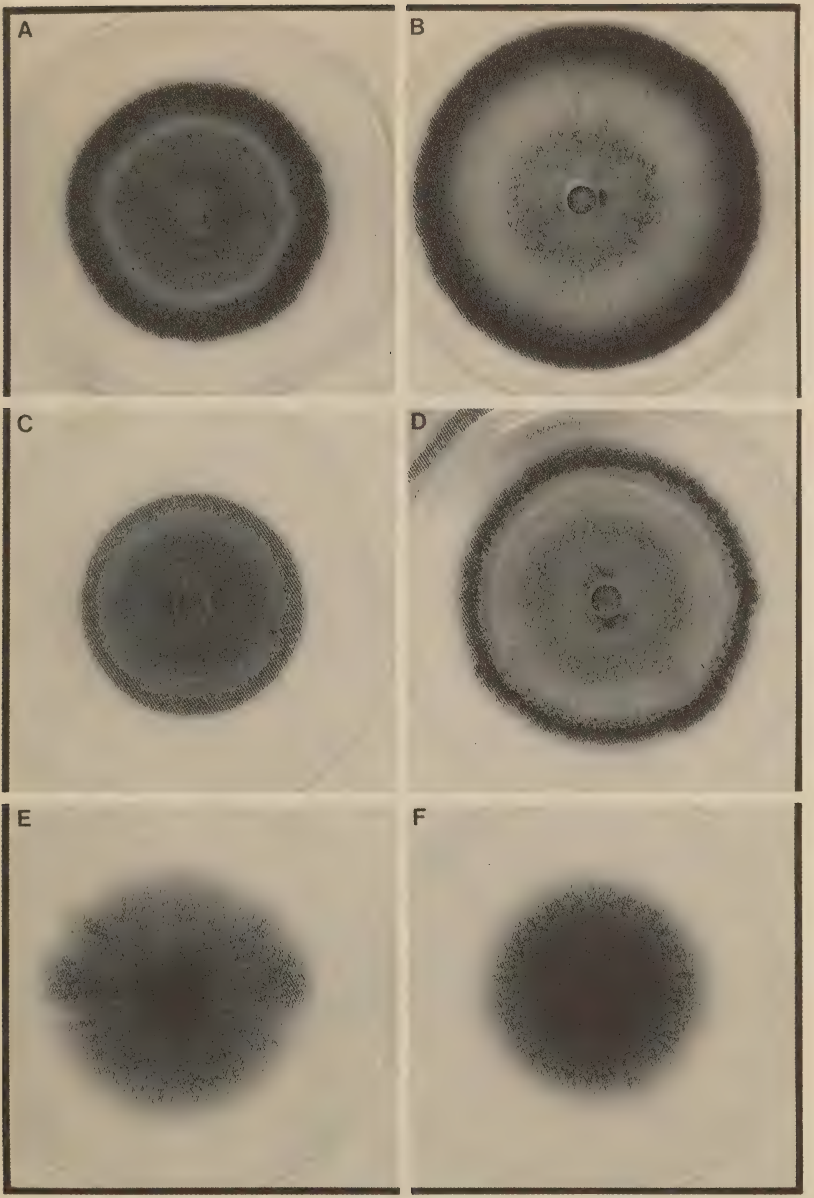


PLATE 1. *Phoma destructiva*. A, 14-day-old colony on PDA at 25C; B, 17-day-old colony on PDA at 25C; C, 10-day-old colony on PDA at 20C; D, 14-day-old colony on PDA at 20C; E, 12-day-old colony on MEA at 25C; F, 12-day-old colony on MEA at 20C.

≡ *Diplodina destructiva* (Plowr.) Petrak, *Ann. mycol.* 10: 19, 1921.

= *Phyllosticta lycopersici* Pk, *Bull. N.Y. St. Mus.* 219-220: 55, 1887.

Colonies on PDA [Difco] after 14 days (Plate 1, A & B) velvety to lanose at first, pale olivaceous-gray to dove-gray to charcoal-gray, broadly zonate, with a narrow, cream-colored marginal zone, a very dark submarginal zone followed inwards by a broad dove-gray zone and a slightly darker center, darkening with age and becoming felted, sometimes with a wide, blackish peripheral zone with very little aerial mycelium; attaining a diameter of 55 mm at 20C after 10 days in the dark and 60 mm at 25C, with no growth at 30C; reverse black, paler at the extreme margin. Colonies on PDA after 21 days dark gray to blackish brown with much of the aerial mycelium over the outer two-thirds collapsed on to the agar surface and thereby giving the appearance of being sparse. Colonies grown at 20C generally more evenly colored and somewhat darker (Plate 1, C & D) but sometimes sectoring, velvety and never lanose. On MEA [Difco] (Plate 1, E & F) colonies with little or no aerial mycelium, olive-green, striate, with several faster-growing fan-shaped sectors usually apparent when grown at 25C; colonies grown at 20C generally darker and more distinctly striate; attaining a diameter of 57 mm at 20C after 10 days and 69 mm at 25C. Mycelium composed of two kinds of hyphae: hyaline, smooth, thin-walled, substantially branched, widely septate, flexuous, 1.5-3 µm wide; and pale to mid brown, smooth, thick-walled, occasionally branched, closely septate, more or less straight, 4-5 µm wide. With age, individual cells of the pigmented hyphae frequently becoming inflated to 9-10 µm in diameter and occasionally assume a chlamydospore-like, toruloid appearance (Plate 2, F & G; Figure 1, E). Pigmented hyphae often aggregated into parallel strands of two to several (Plate 2, A). In young colonies on PDA, such strands readily apparent overlying a mat of the thinner-walled, unpigmented hyphae. Pycnidial initials originating mostly from pigmented hyphae, or from both types of hyphae together, subhyaline (Plate 2, B). Pycnidia produced on PDA and oatmeal agar abundantly, sometimes surrounded by toruloid hyphae especially in older cultures, immersed or superficial, scattered and single or gregarious in confluent clusters of several, especially on OA, subglobose or elongate or somewhat irregular in shape, especially when confluent, brown, paler above, pseudoparenchymatous, without a clearly defined ostiole, up to 190 µm in diameter, mostly 100-130 µm. Pycnidial wall (Plate 2, C & D) composed of an outer layer, mostly two to three cells thick, of pale brown, relatively thick-walled, subglobose to ellipsoid or more or less oblong, angular, frequently compressed or, in older pycnidia, highly contorted cells, and an inner layer, three or more cells thick, of subhyaline, thinner-walled, ellipsoid to oblong cells. Ostiole indistinct, lysigenous. Conidiogenous cells undifferentiated from other inner wall cells. Conidia enteroblastic, oblong to ellipsoid or narrowly obovoid, straight or a few very slightly curved, unicellular, thin-walled, smooth, guttulate or eguttulate, 3.5-6 X 2-2.5 µm.

On *Lycopersicon esculentum*; cosmopolitan.

Collections examined: isolated from *L. esculentum* leaf lesion, Kauai, Hawaii, U.S.A., 1967, F.P. Obrero, ATCC 24636; isolated from fruit of *L. esculentum* imported into New Zealand from Tonga, 1968, G.F. Laundon, CBS 378.73. [Both of these were listed as representative cultures of *P. destructiva* by Boerema and Dorenbosch (1973).]

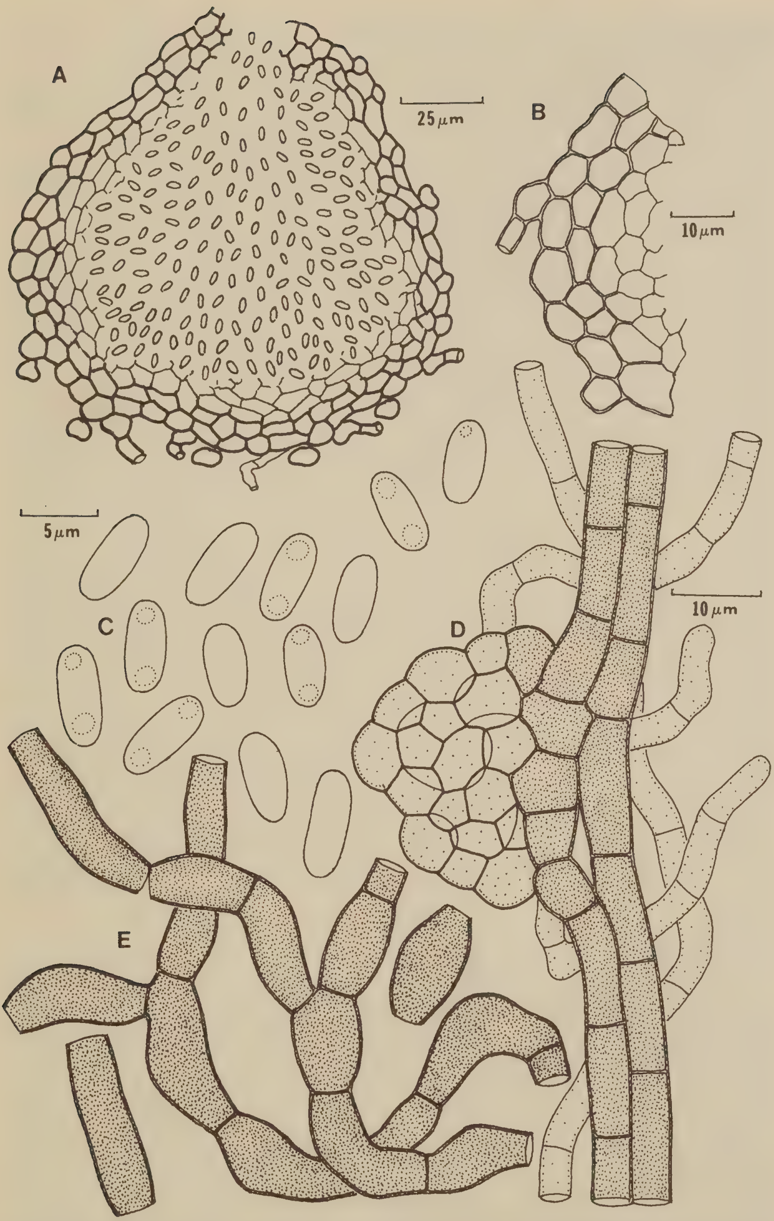

A
25 μm
B
10 μm
5 μm
C
D
10 μm
E

FIGURE 1. *Phoma destructiva*. A, V.S. pycnidium; B, portion of pycnidial wall in section; C, conidia; D, pycnidial primodium; E, toruloid hyphae.

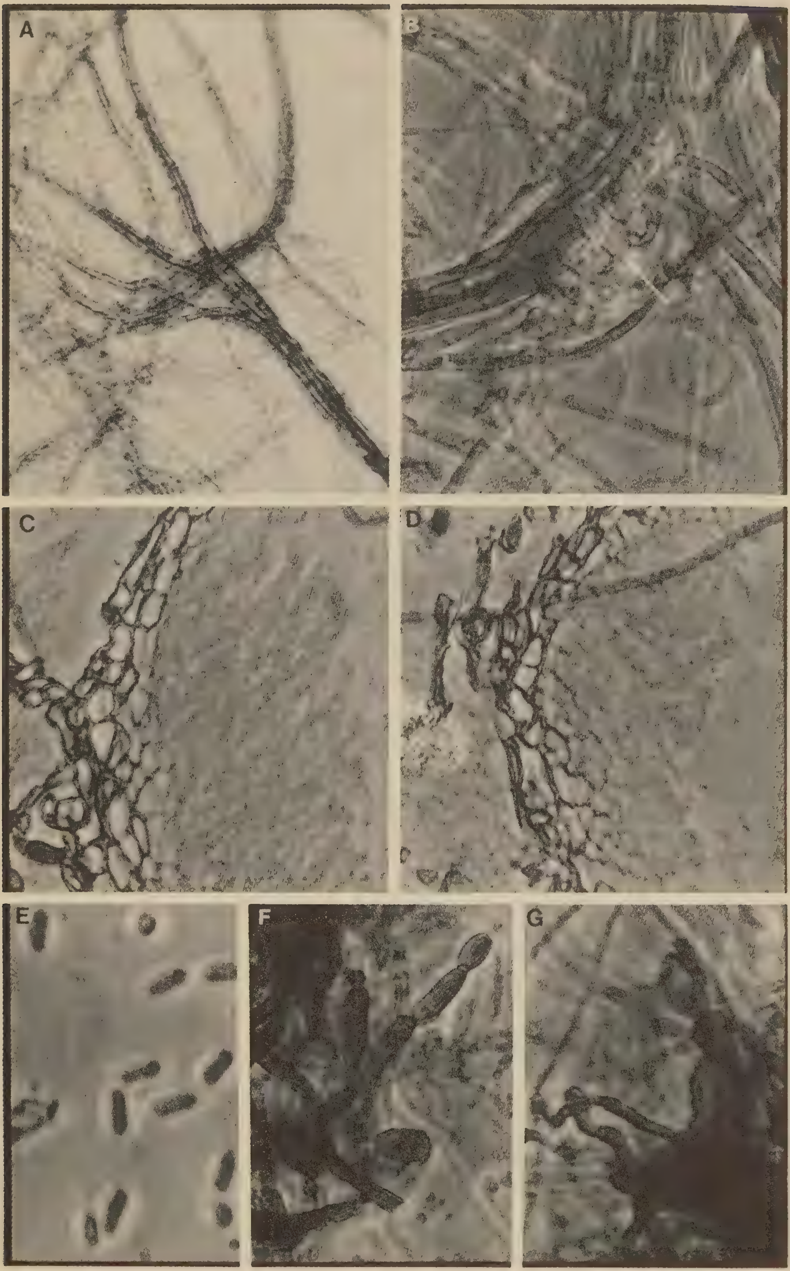
DISCUSSION

Some of the differentiating features of *P. destructiva* and other species of *Phoma* known to occur on tomato, particularly *P. exigua* var. *exigua* and *P. lycopersici*, have been alluded to in the immediately preceding paper of this series (Morgan-Jones and Burch, 1988). In colony appearance *in vitro* on PDA, *P. exigua* is distinctive in having a prominently lobed margin. That species, which will be treated in the next paper in this series, can also be distinguished by greenish discoloration of the agar medium on which it is grown upon application of a drop of NaOH. Within one hour the color changes to a reddish-brown (Boerema and Höweler, 1967). The black, often gregarious and frequently coalescing pycnidia produced abundantly by *P. exigua* var. *exigua* on PDA, coupled with the irregularly shaped margin, give its colonies a bedraggled aspect, as noted by Laundon (1971). It is appreciably faster growing than either *P. destructiva* or *P. lycopersici*. Conidia of *P. exigua* and *P. lycopersici* are generally larger, have a wider size range, and are somewhat more variable in shape than those of *P. destructiva*. Laundon (1971) noted that *P. exigua*, when grown in light on potato/yeast extract/dextrose agar, forms pycnidial clusters whereas, under these conditions, *P. destructiva* and *P. lycopersici* do not. Whether pycnidia are formed singly or in clusters is, however, a variable characteristic, in part dependent on the substrate. *Phoma destructiva*, when grown on PDA, produces predominantly solitary pycnidia, but on oatmeal agar pycnidial clusters are frequent and pycnidia are often confluent.

TABLE 1. Main distinguishing characteristics of *Phoma* spp. associated with fruit and stem rots of tomato, grown on PDA at 25C in the dark for 14 to 21 days (note: each taxon is somewhat variable and individual isolates may not always match up in respect to all colony features).

P. destructiva	*P. lycopersici*	*P. exigua var. exigua*
Colonies velvety, olivaceous to dove gray, with an even margin, aerial hyphae generally sparse, especially in a wide marginal zone. Dark hyphal strands abundant.	Colonies gray to olivaceous brown, often mottled, becoming felted, generally with abundant aerial mycelium, bearing sterile, stilboid tufts of hyphae.	Colonies somewhat variable, aerial mycelium becoming dark olivaceous to black, with a distinctly scalloped or lobed margin, giving a bedraggled appearance, NaOH turning agar blue-green.
Pycnidia abundant, solitary or gregarious, often surrounded in older cultures by toruloid hyphae.	Pycnidia produced more sparsely, slow maturing, mostly solitary.	Pycnidia generally abundant, in dense clusters, sometimes confluent, subtended by a matrix of swollen, pigmented hyphal cells.
Conidia unicellular, often biguttulate, regular in size, 3.5-6 um long.	Conidia frequently bicellular, 3-11 um long.	Conidia frequently bicellular, somewhat variable in shape, 4-12 um long.

PLATE 2. *Phoma destructiva*. A, Hyphal strands; B, pycnidial initial (indicated by arrow); C & D, pycnidial wall in section; E, conidia; F & G, toruloid hyphae surrounding mature pycnidia.


A
B
C
D
E
F
G

Distinctions between *P. destructiva* and *P. lycopersici* are less clear cut than between those species and *P. exigua*. We agree with Sutton (1980) that they are quite close although there can be no doubt that each is a good form-species. Based on the isolates examined by us, although there are some essential similarities, they can be distinguished, among other characteristics, by gross colony appearance. The thick-walled, closely septate, pale brown hyphae that are sometimes aggregated in strands are present in both but the tendency for these to be arranged in parallel strands is better developed in *P. destructiva*. Colonies of *P. destructiva* grow faster than those of *P. lycopersici* on PDA and MEA at 25C and are generally more evenly colored. The sterile stilboid bodies that are produced by *P. lycopersici* in three-week-old colonies on PDA and other media, such as oatmeal agar, are absent in *P. destructiva*. A substantial proportion of the conidia of *P. lycopersici* are not only appreciably larger than those typical of *P. destructiva* but many become medianly 1-septate. Young pycnidia of *P. destructiva*, produced superficially on PDA, often appear hairy due to aerial hyphae radiating from them. In three-week-old cultures on both PDA and oatmeal agar, pycnidia are often enmeshed in a network of thick-walled, inflated, frequently contorted, mid brown hyphae (Plate 2, G), individual elements of which are occasionally chlamydospore-like (Plate 2, F). Such hyphae sometimes disarticulate into individual cells. These are somewhat similar (Figure 1, E) to the so-called toruloid state of *Hendersonula toruloidea* Nattrass, which Punithalingam and Waterston (1970) refer to as thallospores. Pycnidial initiation occurs in a similar fashion in both species and the ontogeny of the pycnidia appears to be similar. Pycnidial initials of *P. destructiva* are ascostroma-like in their structure. The remarks made about *P. lycopersici* with regard to similarity of its pycnidia to pseudothecia (cf. Morgan-Jones and Burch, 1988) also hold true for those of *P. destructiva*. In *P. destructiva*, a few adjacent cells in a pale brown hypha become inflated and this is followed by cell division, which gives rise to a ball of subhyaline cells. During the course of this process, one or more narrower hyaline hyphae may or may not intermingle with these cells. As alluded to in the case of *P. lycopersici* (Morgan-Jones and Burch, 1988), it is quite difficult to determine how conidiogenesis occurs. During the process of pycnidial maturation, the eventual venter of the conidioma is formed by progressive breakdown of some of the internal cells of the primodium. The development of a cavity in this manner is well documented in *Phoma*, for example in *P. betae* Franck [anamorph of *Pleospora betae* (Berl.) Nevedovsky] by Archer (1926), and in some other genera such as *Septoria* Sacc. and *Ascochyta* Lib. (Punithalingam 1966, 1979, respectively).

The sequence of events involved in conidiogenesis in at least several *Phoma* species is, however, somewhat uncertain. Although most species bear a series of phialidic, relatively persistent conidiogenous cells lining the pycnidial venter, each of which produces a succession of conidia, others apparently do not. In *P. destructiva* and *P. lycopersici*, cells from which conidia are produced remain undifferentiated from other internal pycnidial wall cells and no periclinal thickening, indicative of the production of a plurality of conidia, can be observed. In the past, a number of authors have grappled with the problem of interpreting conidiogenesis in pycnidial fungi lacking any obvious conidiogenous cells. Several have described endogenous or partly endogenous differentiation of conidia. The difficulty of determining precisely how conidia are differentiated is compounded by the small size of the conidiogenous cells, their position within pycnidia which makes observation troublesome, and the fact that they sometimes break down rather readily following conidiation. Higgins (1920) described and illustrated a pycnidial synanamorph of *Cercospora bolleana* (Thüm.) Speg. [≡ *Pseudocercospora bolleana* (Thüm.) Sivanesan; teleomorph = *Mycosphaerella* *bolleana* Higgins] differentiating spermatia by endogenous cleavage of the protoplast of each mother cell into four entities. Each of these was eventually extruded into the venter, one at a time, through one or two so-called sterigmata. Von Höhnel (1923) described a process of conidium formation by cleavage within a conidiogenous cell and made this the basis for recognizing a division, named Endogenosporae, in his scheme for classifying pycnidial, acervular and sporodochial fungi. Such conidia were considered to be liberated by histolysis of the mother cell walls. The validity, in this regard, of some past observations is open to question and the extent of occurrence, if any, of endogenous conidium formation is still, at least a partially unresolved question. Petrak (1924) accepted the concept of endogenous origin but reported finding it in only some of the taxa in which von Höhnel thought it to occur. Punithalingam (1979) described a series of events during the process of conidiation in the genus *Ascochyta in vitro* whereby the pycnidial wall progressively breaks down outwards from the center of a more or less solid, expanding primodium. This breakdown is initiated prior to start of conidiation by dissolution of cells toward the center of the primodium, following which undifferentiated conidiogenous wall cells lining the venter become dislodged or sloughed off from their underlying counterparts. The latter are then exposed and assume a conidiogenous function. Once one layer of conidiogenous cells dislodges, the underlying layer of cells becomes fertile and the process is repeated continuously, resulting in an increase in size of the venter, but a commensurate decrease in pycnidial wall thickness. Conidia were described as originating as thin, apical protrusions from such cells and their ontogeny to be holoblastic. The dislodged cells, referred to as temporary conidiogenous cells, were reported to break down soon after conidiation. Each was found to give rise to a single conidium or, occasionally, to divide into two or even four daughter cells. Each daughter cell produced one conidium. Photographic illustrations of conidiogenous cells undergoing cleavage were provided, one of which is reminiscent of the drawing of the similar phenomenon documented by Higgins (1920). Internal disorganization of the pycnidial wall was said by Punithalingam (1979) to cease "by the automatic regulation of the lysigenous process and also the dissipation of the internal pressure necessary to rupture the cell layers, by formation of an ostiole". At that stage of development, attached conidiogenous cells lining the venter were said to remain *in situ* and function as persistent phialides in the manner normally found in a large number of pycnidial genera.

In *P. destructiva* and *P. lycopersici*, it is evident that there is progressive dissolution of the internal cells of the pycnidial primodium but the precise ontogeny of the conidia has not been determined. It seems possible that, as pycnidial wall cells break down, their contents become converted into conidia. Since our main purpose at present is to describe the morphological features of *Phoma* species *in vitro*, detailed studies of conidiogenesis have not been undertaken.

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TAXONOMY OF VA MYCORRHIZAL FUNGI: CLASSIFICATION, NOMENCLATURE, AND IDENTIFICATION

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I. INTRODUCTION

Frank (1885) first coined the term "mycorrhiza" to describe plant-fungus associations. Mycorrhizae are formed by diverse fungi spanning the Zygomycetes, Ascomycetes, and Basidiomycetes (Harley and Smith, 1983). Zygomycetous endomycorrhizae are the most abundant and widespread, forming in the roots of many Angiosperms, Gymnosperms, Pteridophytes, and Thallophytes (Mosse et al., 1981). In recent years, these associations have been referred to as "vesicular-arbuscular mycorrhizae" (VAM), even though some of the fungal symbionts involved do not produce intraradical vesicles. Despite this discrepancy, zygomycetous endomycorrhizae will be synonymous with VAM throughout this review. The fungal symbionts are ubiquitous soil-inhabitants which must colonize plant roots to grow and reproduce. They have been found in diverse habitats ranging from the arctic to the tropics, arid to aquatic environments, and stable plant communities to highly disturbed ecosystems. Physiological specialization appears to be absent in plant hosts, with a single fungus capable of infecting a wide range of host species (Graw, 1979; Mosse et al., 1981).

Extensive research, especially during the past 20 years, has demonstrated that VAM are crucial organs for improving plant growth and survival in agricultural, horticultural, and natural ecosystems. Numerous studies have been conducted to elucidate anatomy and morphology of mycorrhizal infection; dynamics of infection establishment, development and spread; mineral nutrition and physiology of host-symbiont interactions; ecology of mycorrhizal associations; and inoculum production and its application in the field. Analyses of results have been amply discussed in recent reviews by Abbott (1982), Barea and Azcon-Aquilar (1983), Mosse (1981), Mosse et al. (1981), in a book by Harley and Smith (1983), and in books edited by Powell and Bagyaraj (1984), Safir (1987), and Schenck (1982).

Fundamental biological and ecological concepts, however, have been slow to emerge. Partly, this can be attributed to a stronger focus on the mycorrhizal association than on specific fungal symbionts. Titles of research papers often have included the all-encompassing phrases "VA mycorrhizae" or "VA mycorrhizal fungi" to report specific interactions, fostering a perception that different fungi function equivalently. However, evidence is mounting that individual species differ significantly in their effectiveness to promote growth with changes in soil fertility (Abbott and Robson, 1978), soil pH (Hayman and Tavares, 1985), and drought (Allen and Boosalis, 1983). Ecotypes have been identified which are adapted to soils containing high concentrations of heavy metals (Gildon and Tinker, 1983), aluminum (Adelman and

Morton, 1986) and salt (Allen and Cunningham, 1983). Differences in growth responses by different strains of a fungus even have been reported (Haas and Krikun, 1985), although no evidence was provided to support the veracity of species/strain identification.

Experiments using specific VA mycorrhizal fungi often have been difficult to repeat, either because living cultures were not available or identity of the organism(s) could not be verified. Few experimental cultures have been maintained or preserved in personal or institutional herbaria. The confusion that results in the absence of such a practice is exemplified in the "*Glomus fasciculatum*" complex. This group of fungi has been cited as one species in studies performed worldwide, giving the impression of a ubiquitous organism with considerable genetic and physiological plasticity. Identification, however, was based on a broad species description (Gerdemann and Trappe, 1974). A more restricted definition of the fungus has led to the segregation of many isolates previously identified as *G. fasciculatum* into different taxa (Walker and Koske, 1987). The absence of any means to confirm or establish identity of these fungi prevents consolidation of biological or ecological information at the species level.

Taxonomic changes (and progress) are persistent sources of frustration for many mycorrhizal researchers. This stems, in part, from the way mycorrhizal research has evolved and is structured today. Most researchers have developed a working expertise of VA mycorrhizal fungi to fulfill secondary, rather than primary, research objectives. Few scientists have been hired in recent years to develop research or teaching programs with a major focus on mycorrhizae. Training is informal and requires considerable time and energy which often is at odds with other commitments. Yet research priorities now demand that the identity and biology of an experimental organism be as carefully defined as possible.

The purpose of this review is to evaluate critically all criteria presently used to classify and identify VA mycorrhizal fungi, to assess problem areas, and to suggest some approaches needed to clarify taxonomy concepts.

Currently, 126 species of VA mycorrhizal fungi have been described in the literature. These are listed below with authorities. Species with an asterisk after the name are described as having two morphotypes. Superscripts indicate citations of species descriptions in this list and in Section VII.

Acaulospora Gerd. & Trappe emend. Berch[5]

appendicula Spain et al.[41]
bireticulata Rothwell & Trappe[37]
delicata Walker et al.[58]
denticulata Sieverding & Toro[45]
dilatata Morton[29]
elegans Trappe & Gerd.[14]
foveata Trappe & Janos[18]
gerdemannii Schenck & Nicol.[33]
lacunosa Morton[29]
laevis Gerd. & Trappe[14]
longula Spain & Schenck[41]
mellea Spain & Schenck[41]
morrowae Spain & Schenck[41]
myriocarpa Spain et al.[40]
nicolsonii Walker et al.[59]
rehmii Sieverding & Toro[45]
rugosa Morton[29]
scrobiculata Trappe[49]
spinosa Walk. & Trappe[57]
sporocarpia Berch[5]
trappei Ames & Linderman[1]
tuberculata Janos & Trappe[18]

Entrophospora Ames & Schneider[2]

colombiana Spain & Schenck[41]
infrequens (Hall) Ames & Schneider[2,15]
schenckii Sieverding & Toro[43]

Gigaspora Gerd. & Trappe[14]

albida Schenck & Smith[39]
candida Bhattacharjee et al.[10]
decipiens Hall & Abbott[16]
gigantea (Nicol. & Gerd.) Gerd. & Trappe[14,32]
margarita Becker & Hall[4]
rosea Nicol. & Schenck[33]

Glomus Tulasne & Tulasne[14,52]

aggregatum Schenck & Smith emend. Koske[19,39]
albidum Walker & Rhodes[55]
*ambisporum** Schenck & Smith[45]
arborense McGee[27]
australe (Berk.) Berch[6]
boreale (Thaxter) Trappe & Gerd.[14,48]
botryoides Rothwell & Victor[38]
caledonium (Nicol. & Gerd.) Trappe & Gerd.[14,32]
canadense (Thaxter) Trappe & Gerd.[14,48]
cerebriforme McGee[27]
citricola Tang & Zang[47]
claroideum Schenck & Smith[39]
clarum Nicol. & Schenck[33]
constrictum Trappe[49]
convolutum Gerd. & Trappe[14]
delhiense Mukerji et al.[31]
deserticola Trappe et al.[51]
diaphanum Morton & Walk.[41]
*dimorphicum** Boyetchko & Tewari[11]
etunicatum Becker & Gerd.[3]
fasciculatum (Thaxter) Gerd. & Trappe emend. Walker & Koske[14,55]
fecundisporum Schenck & Smith[39]
flavisporum (Lange & Lund) Trappe & Gerd.[14]
formosanum Wu & Chen[60]
fragile (Berk. & Broome) Trappe & Gerd.[14]
fuegianum (Spegazzini) Trappe & Gerd.[14]
fulvum (Berk. & Broome) Trappe & Gerd.[14]
geosporum (Nicol. & Gerd.) Walker[32,53]
gerdemannii Rose et al.[36]
globiferum Koske & Walker[23]
glomerulatum Sieverding[42]
halonatum Rose & Trappe[35]
*heterosporum** Smith & Schenck[45]
hoi Berch & Trappe[8]
intraradices Schenck & Smith[39]
invermaium Hall[15]
lacteum Rose & Trappe[35]
leptotichum Schenck & Smith[39]
macrocarpum Tul. & Tul.[52]
maculosum Miller & Walker[28]
magnicaule Hall[15]
manihotis Howeler et al.[41]
melanosporum Gerd. & Trappe[14]
microaggregatum Koske et al.[24]
microcarpum Tul. & Tul.[14,52]
monosporum Gerd. & Trappe[14]
mosseae (Nicol. & Gerd.) Gerd. & Trappe[14,32]
multicaule Gerd. & Bakshi[13]
multisubstensum Mukerji et al.[31]
occultum Walker[53]
pallidum Hall[15]
pansihalos Berch & Koske[7]
pubescens (Sacc. & Ellis) Trappe & Gerd.[14]
pulvinatum (Henn.) Trappe & Gerd.[14]
pustulatum Koske et al.[26]
radiatum (Thaxter) Trappe & Gerd.[14,48]
reticulatum Bhattacharjee & Mukerji[9]
scintillans Rose & Trappe[35]
segmentatum Trappe et al.[50]
tenebrosum (Thaxter) Berch[6,48]
tenerum Tandy emend. McGee[27,46]
tenue (Greenall)Hall[15]
tortuosum Schenck & Smith[39]
tubaeforme Tandy[46]
versiforme (Karsten) Berch[6]
vesiculiferum (Thaxter) Gerd. & Trappe[14,48]
warcupii McGee[27]

Sclerocystis Gerd. & Trappe[14]

clavispora Trappe[49]
coccogena (Pat.) von Hohn[48]
coremioides Berk. & Broome[14,48]
dussii (Pat.) von Hohn[14,48]
microcarpus Iqbal & Bushra[17]
pachycaulis Wu & Chen[60]
pakistanica Iqbal & Bushra[17]
rubiformis Gerd. & Trappe[14]
sinuosa Gerd. & Bakshi[13]

Scutellospora Walker & Sanders[56]

alborosea (Ferr. & Herr.) Walker & Sanders[12]
aurigloba (Hall) Walker & Sanders[15]
calospora (Nicol. & Gerd.) Walker & Sanders[32]
coralloidea (Trappe et al.) Walker & Sanders[14]
dipapillosa (Walk. & Koske) Walker & Sanders[21]
erythropa (Koske & Walk.) Walker & Sanders[20]
fulgida Koske & Walker[22]
gilmorei (Trappe & Gerd.) Walker & Sanders[14]
gregaria (Schenck & Nicol.) Walker & Sanders[33]
heterogama (Nicol. & Gerd.) Walker & Sanders[32]
minuta (Ferr. & Herr.) Walker & Sanders[12]
nigra (Redhead) Walker & Sanders[14,34]
pellucida (Nicol. & Schenck) Walker & Sanders[33]
persica (Koske & Walker) Walker & Sanders[21]
reticulata (Koske et al.) Walker & Sanders[25]
savannicola (Ferrer & Herrera) Walker & Sanders[12]
tricalypta (Herr. & Ferr.) Walker & Sanders[12]
verrucosa (Koske & Walker) Walker & Sanders[21]
weresubiae Koske & Walker[22]

II. CLASSIFICATION

Classification involves the arrangement of similar organisms into taxonomic groups (taxa) of different rankings according to selected characteristics or common developmental and evolutionary relationships. Most changes in classification reflect altered perceptions of phylogenetic affinities as new species and facts are discovered.

Formulation of a classification system for VA mycorrhizal fungi has not been an easy task. The monograph of Gerdemann and Trappe (1974) established a "temporary" classification system and provided an orderly framework within which scientists could conduct research. However, most taxonomic efforts since then have concentrated more on the description of new species (96 since 1974) than on the evaluation of taxonomic relationships.

The fossil record has not provided many clues of evolutionary relationships important in defining a stable classfication system. Efforts to study reproductive spore development (ontogeny) have been thwarted by the inability to culture VA mycorrhizal fungi axenically (Hepper, 1974). Arbuscule-like structures and intraradical vesicles (or spores) have been observed in primitive angiosperms, but fossilized spores are poorly preserved and bear resemblence only to taxa in two genera of VA mycorrhizal fungi (*Glomus* and *Sclerocystis*) (Berch, 1986).

Host specificity cannot be used in classification because few fungal taxa show any evidence of being limited to associations with particular species. Anatomical features of mycorrhizae also have not proven distinctive enough among taxa to promote their inclusion in classification.

Currently, morphology and germination characteristics of anamorphs are used to classify VA mycorrhizal fungi in the division Eumycota, class Zygomycetes, order Endogonales, family Endogonaceae (Trappe, 1982). Only the type genus, *Endogone*, is classified according to characteristics of the teleomorphic stage (sporocarpic zygospores). Also, members of this genus show no evidence of forming VAM.

Early history of classification of the Endogonaceae is thoroughly discussed by Gerdemann and Trappe (1975), so only a brief summary will be presented here. Most VA mycorrhizal fungi known at that time were sporocarpic. This habit, because of its evolutionary significance, was given "a priori" primacy in classification. Thaxter (1922) was the first to monograph the Endogonaceae, wherein he defined four genera consisting of sporocarpic species: *Endogone* Link: Fries, *Glaziella* Berk., *Sclerocystis*, and *Sphaerocreas* Sacc. & Ellis. Later, *Sphaerocreas* was synonymized with *Endogone* by Zycha (1935). Chlamydosporic species were not separated from *Endogone* because of similarities in the sporocarpic habit. Thaxter (1922) and Godfrey (1957) considered chlamydosporic species to be anamorphs of zygosporic taxa because of observations of both stages in the same sporocarps of *G. fasciculatum* and *G. microcarpum* (then known as *E. fasciculata* and *E. microcarpa*). Those fungi forming chlamydospores singly in soil, because of morphological affinities to sporocarpic taxa, still were included in *Endogone* (Nicolson, 1968). Mosse and Bowen (1968) did not speculate on the relationship between sporocarpic and ectocarpic species, but they weighted the sporocarp habit as the main criterion for inclusion of fungi in *Endogone*. Gerdemann and Trappe (1974) segregated sporocarpic chlamydospore-forming *Endogone* species into *Glomus*, a genus originally erected by Tulasne and Tulasne (1845). Thirty-four sporocarpic species forming zygospores (*Endogone*), chlamydospores (*Glomus*, *Sclerocystis*, *Glaziella*), and sporangia (*Modicella*) were described or redefined. Another eight species which formed only chlamydospores (*Glomus*) or "azygospores" (*Acaulospora*, *Gigaspora*) also were described. Since 1984, *Modicella* and *Glaziella* have been excluded from the Endogonaceae. The former was transferred to the Mortierellaceae (Trappe and Schenck, 1984) and the latter was identified as an ascomycete fungus (Gibson et al., 1986b). A new genus, *Entrophospora*, was erected by Ames and Schneider (1979) and *Scutellospora* was separated from *Gigaspora* by Walker and Sanders (1986).

Thaxter (1922) and Gerdemann and Trappe (1974) originally placed members of the Endogonaceae in the order Mucorales (Zygomycetes). Hypogeous associations with plants, aseptate hyphae, reproductive structures which ranged from asexual chlamydospores and azygospores to sexual zygospores, and a propensity for sporocarp development constituted the logic of this placement. Benjamin (1979) since has restricted the definition of mucoraceous fungi to encompass those organisms which are predominantly saprobes or nonhaustorial parasites which reproduce asexually by sporangia, sporangiola, merosporangia, and less commonly by chlamydospores, arthrospores, and yeast-cells. He validated the order Endogonales as originally proposed by Moreau (1953) and included Endogonaceae in it as the sole family. This classification scheme presumed that these taxa form sporangia rarely or not at all. Evidence to date neither refutes or supports such an assumption.

A. Reproductive structures

1. Morphology

Koske et al. (1983) and Walker and Sanders (1986) have suggested using the generic term "spore" instead of "chlamydospore" or "azygospore" to describe anamorphs of VA mycorrhizal fungi, since the true nature of these spores remains unresolved. This approach minimizes misrepresentation of legitimate spore types. However, it also does not call attention to the significant differences which exist between reproductive structures of different taxa of VA mycorrhizal fungi. At the present time, unfortunately, not enough information is available to advance a suitable alternative.

The ultimate criterion for placement of a fungus in the Zygomycetes is the formation of zygospores, although these spores are not commonly formed by many fungi in natural settings. Until recently, *Endogone* was the only genus in the Endogonaceae known to produce zygospores (Gerdemann and Trappe, 1974) (Fig. 1A). Zygospores develop within a zygosporangium formed by the fusion of two gametangia (Berch and Fortin, 1983a; Tandy, 1975). Two haploid nuclei, one from the female and one from the male gametangium, may fuse within the zygospore (Gibson, 1985) or at the time of germination. However, karyogamy has yet to be demonstrated conclusively.

The formation of zygospores after conjugation of germ tubes from paired "azygospores" has been reported only for *Gigaspora decipiens* (Tommerup, 1987). This find clearly places at least one VA mycorrhizal fungus firmly in the Zygomycetes. Mode of conjugation, nuclear events in karyogamy and zygospore development have yet to be published in detail, however. These data are needed to assess if VA mycorrhizal fungi have closer affinities to *Endogone* or to taxa in the Mucorales. The prevailing assumption, lacking concrete evidence to the contrary, is that spores of taxa in *Glomus*, *Sclerocystis*, *Acaulospora*, and *Entrophospora* are anamorphs. In the Zygomycetes, the anamorphic stage may consist of sporangia, unispored or multispored sporangiola, merosporangia, chlamydospores, and azygospores (Hammill, 1981a).

Spores formed by *Glomus* and *Sclerocystis* are borne terminally on one or more hyphae (Fig. 1B, C). Only in *Sclerocystis* are spores formed obligately in sporocarps (Gerdemann and Trappe, 1974). Sporocarpic *Glomus* species form spores arranged randomly in glebal hyphae; taxa in *Sclerocystis* develop spores arranged tightly in a single layer around a central plexus of sterile hyphae (Fig. 1B). The spores of both genera have been defined as chlamydospores because of their thick, pigmented walls (Gerdemann and Trappe, 1974).

Differences between *Glomus* and *Sclerocystis* are becoming less distinct with the description of presumed dimorphic species: *G. ambisporum*, *G. heterosporum*, and *G. dimorphicum*. The sporocarpic form of the first two species consists of chlamydospores organized in a pattern similar to that found in *Sclerocystis*. The possibility that these similarities justify synonymy between the two genera (Walker, 1987) still is highly speculative. First, mycorrhizal status of *Sclerocystis* must be documented in more than just one species and ontogenetic events in sporocarp formation must be clarified. Second, the dimorphic forms of the above-mentioned species must be verified from single-spore cultures grown under gnotobiotic conditions. Finally, stability of the dimorphic states must be assessed under different ecological and environmental pressures.

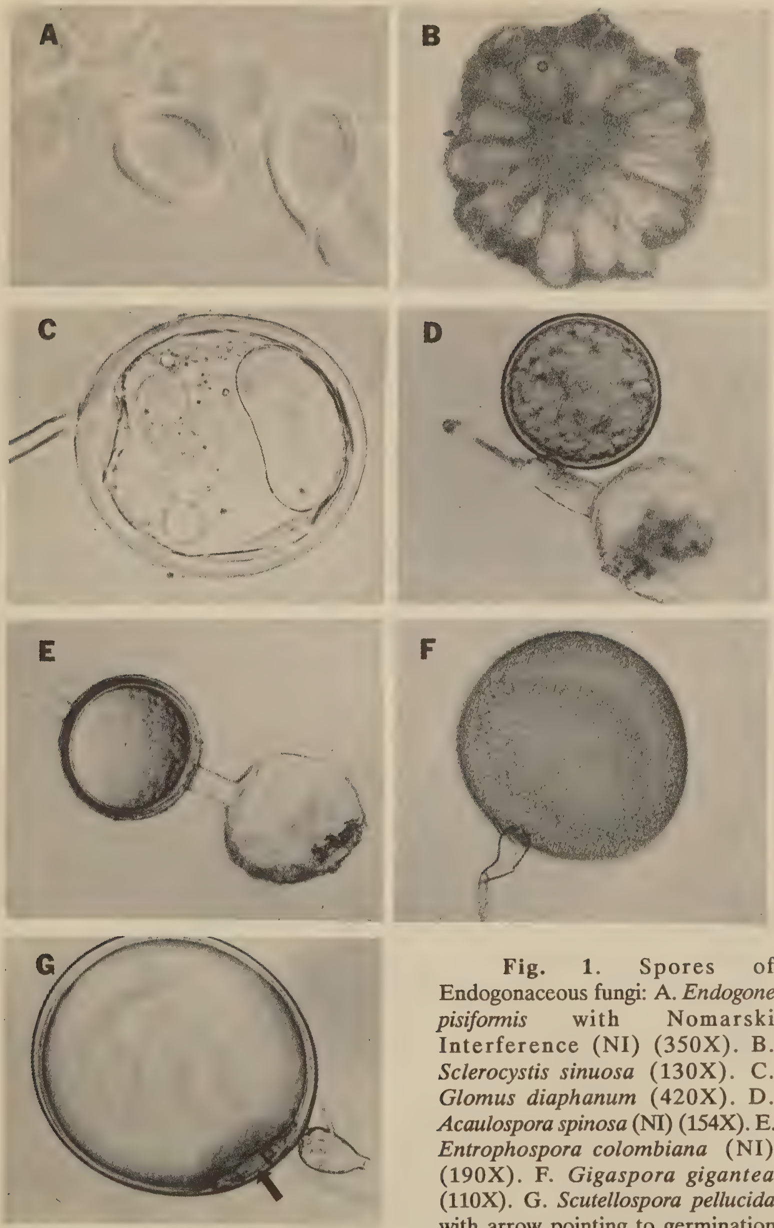

Fig. 1. Spores of Endogonaceous fungi: A. *Endogone pisiformis* with Nomarski Interference (NI) (350X). B. *Sclerocystis sinuosa* (130X). C. *Glomus diaphanum* (420X). D. *Acaulospora spinosa* (NI) (154X). E. *Entrophospora colombiana* (NI) (190X). F. *Gigaspora gigantea* (110X). G. *Scutellospora pellucida* with arrow pointing to germination shield (165X).

The anamorphs of *Glomus* and *Sclerocystis* fit within a very broad definition of chlamydospores. Griffiths (1974), however, defines chlamydospores as thick-walled survival structures formed within vegetative hyphae. An outer wall continuous with the hyphal wall enclosing an inner (usually laminated) second wall is considered essential to the true chlamydospore (Campbell and Griffiths, 1974; Stevenson and Becker, 1972), but this hypothesis is highly controversial. A unispored sporangiolum formed blastically, by comparison, is a spore which develops from a modification of the hyphal wall (Fig. 2A). It usually is thinner-walled than the chlamydospore, dehisces easily, and usually is not solitary (Hammill, 1981b). Both spore types appear to be defined more by function than structure. Unispored sporangiola are considered primary spores because of their importance in dissemination. Chlamydospores may have evolved more for perrenation than dissemination, and hence are of secondary importance (Griffiths, 1974). Current evidence indicates that the spores of *Glomus* and *Sclerocystis* are primary propagative structures, but they also appear to be much less efficient dessiminators than aerial spores (Warner et al., 1987). It is possible that the anamorphs of *Glomus* and *Sclerocystis* are an intermediate form between the two extremes of the more narrowly defined chlamydospores and sporangiola.

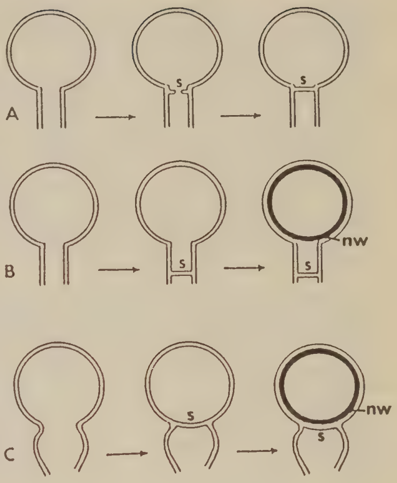

Fig. 2. Comparison of events in the formation of (A) a sporangiolum formed blastically, (B) a sporangium, and (C) an azygospore. nw = new spore wall, s = septum. (from Khan and Talbot, 1975; O'Donnell et al., 1977).

Species in *Acaulospora* and *Entrophospora* form a terminal swollen sac on a single hypha either singly in soil or in sporocarps (Berch, 1985). This sac has been called a "mother spore" (Mosse, 1970a; 1970b), a "vesicle" (Gerdemann and Trappe, 1974), a "hyphal terminus" (Schenck et al., 1984), and a "sporiferous saccule" (Walker, 1984). The spores produced by both genera have been called "azygospores" since the sporiferous saccule resembles an aborted gametangial process (Gerdemann and Trappe, 1974), though evidence of any such origin or function in lacking. In *Acaulospora*, the azygospores form laterally on the hypha subtending the sporiferous saccule (Fig. 1D); in *Entrophospora*, the azygospores form within the neck of the hypha (Fig. 1E). Wall structure, which commonly is used in other fungi to clarify spore ontogeny and type, has not been a focus of attention in either genera until recently. Gibson (1985) and Walker (1987; 1988) suggest that these anamorphs actually may be single-spored sporangia formed on or in the hypha attached to the sporiferous saccule. Berch (1986) coins the term "sporogenous vesicle" to describe "the hyphal swelling within which the spore develops" in *Acaulospora*. However, she makes no mention of evidence supporting the concept of an outer wall continuous with the subtending hypha enclosing the mature spore. In *Entrophospora*, light microscopic evidence indicates more conclusively that the outer spore wall initially is continuous with the hyphal wall. The pore at the point of attachment for most taxa in *Acaulospora* and *Entrophospora* appears to be occluded with spore wall material. Differences in wall structure between that of the spore and the parental hyphae are obvious even at the light microscope. Still, ultrastructural studies of spore ontogeny are needed to confirm these observations.

Some taxa in *Acaulospora* (*A. appendicula*, *A. nicolsonii*, *A. sporocarpia*) form spores on a pedicel branching from the hypha subtending the sporiferous saccule. This pedicel resembles denticles attaching sporangiola to the fertile vesicles of *Cunninghamella* and *Mycotypha* species (Khan and Talbot, 1975). Conceivably, the sporiferous saccule could be a modified fertile vesicle which bears the spore either latterally or internally, with the pedicel reduced or eliminated in most *Acaulospora* species. Origin and morphological details of the pedicel region either are ambiguous or not reported.

Taxa in *Gigaspora* and *Scutellospora* form soil-borne spores terminally on "bulbous suspensor cells", a term denoting their resemblance to the suspensor cells of zygospore-forming mucoraceous fungi (Gerdemann and Trappe, 1974) (Fig. 1F, G). A small filiform hyphal projection often protrudes from the bulbous suspensor cell, branching toward, and sometimes contacting, the outer surface of the spore wall (Fig. 1G). This combination of characteristics led to a perception that these spores were azygospores formed on parthenogenic gametangia (Gerdemann and Trappe, 1974). However, there is no indication of an abortive sexual process nor is their any evidence of a gametangial septum normally evident in mucoraceous fungi with obligate azygosporogenesis (O'Donnell et al., 1977) (Fig 2C).

Unispored sporangiola, formed by many members of the Mucorales, have reduced columellae and are formed on sporophores or on fertile vesicles (Alexopoulis and Mims, 1979; Benjamin, 1979). The bulbous suspensor cell of *Gigaspora* and *Scutellospora* may be similar to a fertile vesicle. The spore, however, is significantly larger than sporangiola of mucoraceous fungi borne on these specialized hyphae. Distinctions between unispored sporangiola and chlamydospores are not clear-cut (see Fig. 2). A sporangiospore can be delineated from the sporangium by a separate and distinct wall. The thin, often adherent, outer wall enclosing a thicker laminated wall in spores of most *Gigaspora* and *Scutellospora* species is suggestive of a sporangial wall [as suggested by Walker (1987)]. Gibson (1985) confirms that the thin outer wall, which stains differentially in azure methylene blue, is continous with the hyphal wall. However, more developmental and cytological studies are needed to ascertain nuclear behavior and the presence or absence of sex hormones. It is unclear if the occlusion between spore and suspensor is similar chemically or ultrastructurally to the laminated wall. If so, it would indicate that the closure is of spore rather than of hyphal origin (Fig. 2B, C).

Spore wall structure, ornamentation of auxiliary cells, and manner of spore germination are fundamental differences which separate *Gigaspora* from *Scutellospora* (Walker and Sanders, 1986). Spores of *Gigaspora* lack any flexible inner walls, whereas those in *Scutellospora* possess at least one flexible inner wall. Auxiliary cells formed by *Gigaspora* are spiny or papillate to varying degrees, whereas those formed by *Scutellospora* are lumpy to knobby. The function of auxiliary cells remains unknown.

They do not appear to function as propagules for initiation of mycorrhizal infection, but they can form hyphae from the subtending hypha of detached cells (Pons and Gianinazzi-Pearson, 1985). Differences in spore germination between the two taxa are discussed in the next section.

2. Germination

Zygospore germination has been reported only for *Endogone pisiformis* Link and *E. incrassata*, but the process differs significantly between the two species. Germ tubes emerge from a membranous structure forming a chamber between the zygospore wall and the zygosporangium wall in the former (Berch and Fortin, 1983a), but directly through the point of attachment to the gametangium in the latter (Berch and Fortin, 1982). Berch and Fortin (1983a) suggest that the germination chamber in *E. pisiformis* may indicate phylogenetic ties between *Endogone* and *Scutellospora*. However, the germination chamber in *Scutellospora* species is morphologically quite distinct from that in *Endogone*.

Spore germination has not been described for any taxon in *Sclerocystis* and only for a few taxa in *Glomus*. Germination in *Glomus* can occur by regrowth of the germ tube through the subtending hypha (Miller and Walker, 1986; Nicolson and Gerdemann, 1968) or emergence of the germ tube directly through the spore wall (Hall, 1977; Walker and Rhodes, 1981). In view of the large number of *Glomus* species and the frequency with which they are used as inoculum in empirical studies, events in germination of additional taxa need more documentation.

Mode of spore germination in *Acaulospora* remains largely unknown. The only published account is by Mosse (1970a; 1970b) in spores identified as *A. laevis*. She describes the formation of an interwall compartment which gives rise to a germ tube directly penetrating outer walls. It is unclear if more than one species is present in this material, since no voucher specimens are available for verification. Confirmation of germination events in this or any other *Acaulospora* species is important because Mosse's observations have been generalized to include other taxa in *Acaulospora*. The manner of spore germination in *Entrophospora* has not been documented in any of the three species currently described. Again, however, affinities in spore morphology have led to the assumption that germination is similar to that of *A. laevis*.

The absence of flexible inner walls in *Gigaspora* correlates so far with emergence of germ tubes directly through the structural wall of spores (Walker and Sanders, 1986). In *Scutellospora*, at least one inner flexible wall is necessary for the formation of a membranous "germination shield" (Fig. 1G). This specialized structure undergoes complex development prior to the emergence of one or more germ tubes. Unlike other genera of VA mycorrhizal fungi which also possess flexible inner walls (e.g. *Acaulospora*, some *Glomus* species), germ tube formation often can be observed in spores of *Scutellospora* extracted directly from field and pot culture soils. As learned from studies on *A. laevis* (Tommerup, 1983), dormancy factors appear to limit the occurrence of germination in *Acaulospora* much more so than in *Gigaspora* or *Scutellospora*.

3. Phylogeny and Diversity

Phenotypic similarities in spore morphology and germination characteristics have been interpreted to indicate phylogenetic affinities among taxa in the Endogonaceae. Unfortunately, the fossil evidence is insufficient to show evidence of distinct changes in morphological development (Berch, 1986). Phenotypic similarities may arise from different evolutionary trends such as: (i) convergence of phenotypes in lines of different origin, (ii) relatively recent divergence of phenotypes in lines of similar origin, or (iii) parallel evolution of phenotypes after divergence in the distant past (Heslop-Harrison, 1962). The "a priori" weighting of sporocarp development in classification of VA mycorrhizal fungi and the limited fossil evidence has downplayed the possibility of convergent evolutionary trends. This and the weight of historical precedence undoubtedly are responsible for the continued placement of *Endogone* and the six genera of VA mycorrhizal fungi together in the same family.

The possibility that taxa within *Glomus* or *Acaulospora* may need to be split into different genera because of consistently different morphological characteristics cannot be ruled out. In *Glomus*, for example, some species have flexible inner walls; others do not. Such flexible inner walls may represent a functional complex necessary for "germination shield" formation as observed in *Scutellospora* (Walker and Sanders, 1986), but no evidence exists to extend this interpretation to these genera. As discussed earlier, several species of *Acaulospora* develop spores on a short pedicel branching from the hypha subtending the sporiferous saccule. It is not known if ontogeny (and phylogeny) of these spores is closer to that of other *Acaulospora* species or to *Glomus*.

Obviously, a vacuum exists regarding light and electron microscopic studies of spore development and germination processes in all taxa of VA mycorrhizal fungi. Improved methods of overcoming problems associated with fixation and sectioning of spores (Gibson, 1985) should stimulate new research in these areas. Changes in spore wall structure and morphological features at the point of attachment between spore and hypha must receive more careful attention. As early as 1922, Thaxter suggested that the primary criterion to delimit species might be microscopic detail at the junction of the spore and subtending hypha.

Morphological affinities of spores of *Endogone* and VA mycorrhizal fungi have been presumed for the most part. Gibson (1985) and Gibson et al. (1986a) observed some ultrastructural similarities: septal perforations in hyphae of several *Endogone*, *Glomus*, and *Sclerocystis* species; similar staining properties of the outer wall of spores of *Glomus etunicatum*, several *Gigaspora* and *Scutellospora* species, and the zygosporangium wall of *E. pisiformis*. The significance of these similarities, however, is difficult to assess. Multiperforate septa occur in other Zygomycetes (Alexopoulis and Mims, 1979), so that these affinities may be most important at the class level.

The morphological affinities pale next to more significant differences in reproductive stages (see above) and events in the symbiotic association between host and endophytic fungus. Walker (1987) already questions the validity of placing VA mycorrhizal fungi together with *Endogone* in the Endogonaceae. A formal move to split the two, however, probably should await more knowledge of ontogenetic relationships.

B. Vegetative structures

As obligate biotrophs (Lewis, 1973), VA mycorrhizal fungi must colonize roots of a living host to grow and reproduce. All taxa in the Endogonaceae except those in *Endogone* are known or presumed to form VAM associations. Haustorium-like arbuscules (Fig. 3A) are the functional and structural organ which link this group of fungi together. Arbuscules are transitory structures, forming within the cells of the inner root cortex (Mosse, 1973). The interface between arbuscule and host cell plasmalemma is considered the main site of nutrient exchange between host and symbiont (Gianinazzi et al., 1979).

Many taxa in *Glomus*, *Sclerocystis*, *Acaulospora*, and *Entrophospora* produce terminal thin-walled vesicles on inter- or intra-cellular hyphae in roots (Fig. 3A) (Gerdemann, 1965; Abbott, 1982). The high lipid and glycolipid content in these structures suggest a storage function (Mosse, 1981). Vesicles of some species may serve as infectious propagules (Biermann and Linderman, 1983), although it is uncertain if these structures were simply not precursors to intraradical spores. *Gigaspora* and *Scutellospora* do not form intraradical vesicles, though they do form fragile extraradical auxiliary cells (formerly called "vesicles"). Gerdemann and Trappe (1974) suggest that these cells may be temporary storage organs or modified subsporangial vesicles.

Characteristics of the endotrophic phase of mycorrhizal associations have never been given much weight in classification below the family level. Peyronel (1924; 1937) associated mycorrhiza formation with several chlamydosporic, sporocarpic species then classified as *Endogone*. Later, Godfrey (1957) and Mosse (1956) observed mycorrhizal infection by species which formed solitary chlamydospores in soil as well as in sporocarps. Spores of other *Glomus* species were found, extracted singly from sieved soil, and then used to synthesize mycorrhizae in open pot cultures (Nicolson and Gerdemann, 1968). Many of the early sporocarpic species (58%) of VA mycorrhizal fungi have never been verified as forming VAM.

The Code of Nomenclature contains no provision that fungal species must be established in monospecific pot cultures for valid publication (Section III). This is reflected in the number of species descriptions documenting pot culture results: 36/67, 2/9, 18/22, 3/3, 4/5, and 15/19 in *Glomus*, *Sclerocystis*, *Acaulospora*, *Entrophospora*, *Gigaspora*, and *Scutellospora* species, respectively. Those taxa not cultured have been assumed to be mycorrhizal because of affinities in spore morphology.

The absence of distinctive interspecific differences in mycorrhizal anatomy at the light microscope level has discouraged more detailed analyses for classification purposes. Most VA mycorrhizal fungi have been reported as forming "typical" vesicular-arbuscular or arbuscular infection in pot culture, although this term has no precise meaning. Significant morphological differences in mycorrhizal development may exist among taxa (Abbott, 1982; McGee, 1986; Morton, 1985), but fewer than 25% of these descriptions indicate method(s) of pot culture establishment or the final degree of purity. It is not surprising that significant morphological differences in mycorrhizal development are ignored or go unnoticed, considering the diversity in hosts and growth media used to set up pot cultures. Host or environment-induced variability may limit the taxonomic value of mycorrhizal structures in general (Hall, 1977; Morton, 1985), but additional studies are needed to evaluate this hypothesis.

Detailed analysis of hyphal morphology of different VA mycorrhizal fungi has been limited to a few published studies (Abbott, 1982; Abbott and Robson, 1979). Results suggest that some aspects of intraradical hypha morphology may be useful to distinguish among genera of VA mycorrhizal fungi. Key characteristics include: (i) mode of branching of hyphae, (ii) pattern and density of vesicle formation, (iii) constrictions, swellings, or projections on intraradical hyphae, (iv) staining intensity of intraradical hyphae, and (v) hyphal diameter. These anatomical features appear to be stable in different host-soil environments (Abbott, 1982). Generalizations about more VA mycorrhizal fungi are impossible, nevertheless, because of the paucity of data.

Most species of *Glomus*, *Acaulospora*, and *Entrophospora* form intraradical arbuscules and vesicles, but some form vesicles rarely or not at all. For a given taxon, vesicles can be highly variable in frequency of occurrence, size, and shape (Morton,

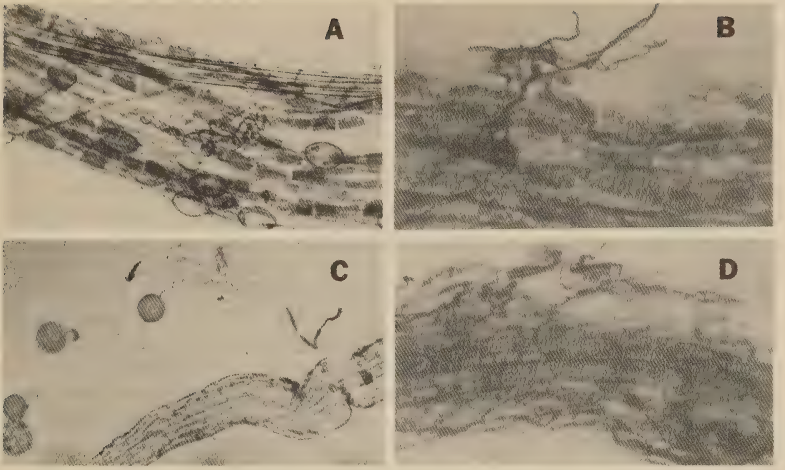

Fig. 3. Characteristics of mycorrhizal infection in roots stained with 0.05% trypan blue. A. Vesicular-arbuscular infection by *G. diaphanum* in *Trifolium pratense* L. (145X). B. Arbuscular infection by *Scutellospora dipurpurescens* Morton & Koske nom. ined. at an entry site on a root of *Sorghum sudanense* (Staph.) Piper (126X). C. The absence of intraradical stained mycorrhizal structures of *G. occultum* despiteabundant sporulation in *S. sudanense* (62X). D. Infection by *Glomus tenue* in *Andropogon virginicus* (75X).

1985). However, some fungi consistently form morphologically distinct vesicles. For example, vesicles formed by *A. laevis*, *G. arborense*, and *G. warcupii* are lobed (Gerdemann and Trappe, 1974), sausage-shaped (McGee, 1986), and coated with a mucilagenous layer (McGee, 1986), respectively. Even in these species, however, stability of vesicle morphology in different environments is unknown, making their taxonomic value questionable.

Because taxa in *Gigaspora* and *Scutellospora* do not form intraradical vesicles, only anatomical features of arbuscules and intraradical hyphae can be studied. The knobby projections described for internal hyphae of *Gigaspora* (Abbott, 1982) rarely have been observed in *Glomus* or *Acaulospora*, but they are common on hyphae of a newly described *Scutellospora* species (Fig. 3B) (Morton and Koske, 1988). Additional details of vegetative hyphae may provide important clues of affinities among taxa as they come to light. Shape and ornamentation of auxiliary cells (see Section IIA) formed by *Gigaspora* and *Scutellospora* are important only at the generic level because of high interspecific variability (Koske and Walker, 1985).

Mycorrhizal anatomy can be observed by staining host roots in trypan blue (Phillips and Hayman, 1970), acid fuschin (Kormanik et al., 1980), or chlorazol black E (Brundrett et al., 1984). A non-destructive approach is to view autofluorescing arbuscules under UV light (450-490 nm excitation range and 520-560 nm emission range) (Ames et al., 1982). Unfortunately, hyphae, vesicles and intraradical spores usually are not visible. Autofluorescence of suberized or lignified root tissue also may mask results. Hyphae and arbuscules of many *Gigaspora* and *Scutellospora* mycorrhizae stain intensely in trypan blue, regardless of host species (Morton, unpub.). Some VA mycorrhizal fungi, such as *A. trappei*, are intermediate in their staining reaction in trypan blue (Abbott, 1982). A growing number of VA mycorrhizal fungi in *Glomus*, *Acaulospora*, and *Entrophospora* are not visible or only weakly visible in host roots treated with the above-mentioned stains: *G. dimorphicum*, *G. fecundisporum*, *G. leptotichum*, *G. maculosum*, *G. occultum*, *G. tortuosum*, *A. myriocarpa*, and *E. schenckii* (Fig. 3C). At least in *G. occultum*, this phenomenon is consistent in different host-soil combinations (Morton, 1985). Intraradical hyphae usually are visible only in a limited number of cortical cells at sites of ingress (Schenck and Smith, 1982). The non-staining properties of these fungi prevent monitoring of arbuscular or vesicular formation during infection development. A rapid increase in spore production by *G. occultum* over time suggests that the fungus is spreading in host roots in the absence of visible infection (Morton, 1985). An incompatibility between stain and cell walls may account for the non-staining properties of intraradical fungal hyphae. Isozyme analysis of mycorrhizal roots (Hepper et al., 1986) or immunological detection assays (Wright et al., 1987) are possible alternative approaches for monitoring mycorrhizal colonization by these fungi.

Another fungal species currently included in the Endogonaceae, *Glomus tenue*, has been termed the "fine endophyte" because it produces very thin extra- and intraradical hyphae (less than 1.5 μm) in fan-shaped patterns (Fig. 3D). Mycorrhizal development is atypical, consisting of small structures which resemble arbuscules and globular vesicles. Hall (1977) includes the fungus in *Glomus* because of the tiny (10-12 μm) dark brown chlamydospores formed in soil. *Glomus tenue* most likely includes several species. Isolates which fit within the description of *G. tenue* can stimulate plant growth (Powell, 1980). Still, some doubt exists as to whether these "fine endophytes" should be included in *Glomus* (Walker, 1988).

Endogone flammicorona Buch. (Chu-Chou and Grace, 1979) and *E. lactiflua* Buch. (Fassi et al., 1969) form ectotrophic mycorrhizae, but the association is unusual in that no fungal mantle is synthesized. *Endogone pisiformis* has been cultured axenically (Berch and Fortin, 1983b), but inoculations on *Pinus* failed to produce a fungal mantle or Hartig net. Most *Endogone* species are considered saprobes (Benjamin, 1979). Although ascomyceteous and basidiomyceteous fungi also form mycorrhizae with higher plants, morphological features as well as physiological interactions are quite distinct in each group (Harley and Smith, 1983). Arbuscular development alone, from a physiological and ecological standpoint, is enough of a distinction to classify genera of VA mycorrhizal fungi apart from *Endogone*.

III. NOMENCLATURE

The naming of a VA mycorrhizal fungus is an absolute necessity before it can be studied experimentally. An International Code of Nomenclature was proposed by De Candolle at the International Botanical Congress held in 1867 in Paris, France to insure that such a process was standardized for all scientists. This Code normally is revised every five years by an International Botanical Congress. The rules set forth in the "International Code of Botanical Nomenclature" (1983) have provided firm guidelines for the description of new taxa.

The bionomial species name consists of a genus name followed by a specific epithet. The latter, when adjectival, must agree grammatically with the generic name. Changes in latin endings of specific epithets in many *Glomus* species were made by

Trappe (1982) to agree with the neuter genus name. Such minor modifications may be mildly irritating to researchers for a time, but they are necessary to preserve consistency in nomenclature.

Nomenclatural types are a corequisite to naming a taxon below the rank of order. The type of a family name is the genus from which the family name was derived (e.g. *Endogone*, Endogonaceae) (Article 10), the type of a genus is a species (Article 10) and the type of a species is a preserved specimen (Article 9). In the last case, a holotype is designated by the author(s) of the species description (Article 7). The species holotype directly links the species epithet with a physical specimen of the organism. A holotype may not always be the most typical representative of a taxon, since it consists of only a single specimen, but the most representative specimen should be selected if at all possible. Holotypes of VA mycorrhizal fungi described so far have consisted of one or more spores mounted on a single slide, a vial of preserved spores, a dried or preserved sporocarp, or an illustration or photograph of one or more spores or sporocarp. The holotype should be deposited in a permanent, responsible institution which will conserve the material and make it available for study by other researchers. Common repositories of VA mycorrhizal fungi include the Farlow Reference Library and Herbarium of Cryptogamic Botany, Harvard University, Cambridge, Mass., U.S.A.; The Herbarium, Department of Botany and Plant Pathology, Oregon State University, Corvallis, Or., U.S.A.; and The Herbarium, Royal Botanical Gardens, Kew, Richmond, Surrey, United Kingdom.

No provision in the Code regulates the quality of the specimen(s) used to name and describe an organism. This has been a persistent problem among VA mycorrhizal fungi, even to the extent that several species descriptions have been published from hyperparasitized material (Bhattacharjee et al., 1982; Mukerji et al., 1983) or spores collected from the stomach contents of small rodents (Rothwell and Victor, 1984). The condition of the holotypes either is too poor to study properly (e.g. *G. botryoides*) or is not accessible for study at all (*G. multisubstensum*, *Gigaspora candida*).

Isotypes represent duplicates of the holotype collection. These often are sent to herbaria other than that in which the holotype is deposited. This practice has become more common in recent years by investigators erecting new taxa, but it is not universal. Type specimens of species described in Cuba (Ferrer and Herrera, 1981), India (Bhattacharjee et al., 1982; Mukerji et al., 1983), Pakistan (Iqbal and Bushra, 1980), China (Tang and Zang, 1984), and Taiwan (Wu and Chen, 1986) have been deposited only at an herbarium in the country of origin. Theoretically, this should not be a problem, but attempts to borrow some of these materials for purposes of verification or comparison of species meet with failure (Koske and Walker, 1985; 1986). The validity of these species cannot be questioned if a type has been deposited with an appropriate institution, but the description of these fungi must be viewed with skepticism until such types are available for examination by other scientists.

Under conditions where the holotype is not designated, or it is lost or destroyed, then a lectotype [selected from the original collection of the author(s)] or a neotype (selected from some other collection displaying similar characteristics) is erected to serve as the reference for the named species. A lectotype was designated for *Glomus macrocarpum* and *Glomus microcarpum* from original collections of the Tulasne brothers, because a holotype had never been designated (Berch and Fortin, 1983c; 1984a). Similarly, a lectotype of *G. fasciculatum* was erected from an original collection of Thaxter from Quebec, although illustrations of the fungus were from a pot culture of an Illinois isolate (Gerdemann, 1965).

The type specimen of non-vascular plants, including fungi, may consist of more than one individual, but this latitude has been a source of problems for classifying VA mycorrhizal fungi from the outset. Thaxter (1922) described sporocarpic species in which single sporocarps contained more than one species. This situation led him to the erroneous conclusion that taxa in *Endogone* produced both zygospores and chlamydospores in the same sporocarp (see Section IIA). Holotypes consisting of a collection of spores in a vial have been known to comprise more than one species, even though the specimen originally was meant to represent a population of a distinct taxon (Walker, 1987). When such an event occurs, serious problems develop for future taxonomists. A lectotype must be erected which best corresponds to the original description. This becomes difficult if the description is vague and living specimens cannot be found. Walker (pers. comm.) has recommended that the holotype consist of a single spore on one slide to prevent confusion for future investigators. A vial containing spores from the same population also should be included, but designated as an isotype. Following this practice, efforts should be made to insure the holotype is perserved in a permanent mountant (e.g. PVL or PVA). However, the effects of such preservatives on spore morphology during storage must be kept in mind (see Section IVC). This problem is surmountable by including one or more black and white photographs showing pertinent diagnostic characteristics of a freshly mounted spore together with the holotype. An example of such a situation is *A. bireticulata*. The holotype specimen consists of two slides, with a single spore per slide: one stained in trypan blue and the other immature. A black and white photograph showing internal wall structure in a broken spore also is included in the packet (Morton, unpubl.). This photo provided the physical evidence needed to confirm an identification despite discrepancies in the species description (Rothwell and Trappe, 1979).

A living culture is prohibited as a holotype (Article 9). "Type cultures",as designated for bacteria, are inappropriate for fungi. Van Beverwijk (1961) suggested the term "culto-type" to represent the living cultures from which the holotype is extracted. In 1985, NSF funded a project aimed at establishing an international culture collection of VA mycorrhizal fungi (INVAM) at the University of Florida to: (i) preserve germplasm, (ii) improve methods for propagation and perservation, (iii) train scientists, and (iv) provide source material for study. Presently, N. C. Schenck and Y. Perez are Curator and Assistant Curator of INVAM, respectively. This facility provides the ideal opportunity for researchers to deposit "culto-types" or living isotype and paratype cultures, which can then be preserved as living germplasm accessible to future scientists.

Part of the problem with current classification and identification of VA mycorrhizal fungi is the imperfect manner in which species are described. Names of fungi are valid only if they are published in a scientific journal with a latin description (Articles 29 and 36). These protologues (everything associated with a name at its valid publication) include observations interpreted according to taxonomic concepts known at the time a new taxon is proposed. As facts emerge or change, it becomes necessary to re-evaluate descriptions of taxa. For example, recent revisions concerning *Scutellospora* species (Koske and Walker, 1985; 1986) and *G. fasciculatum* (Walker and Koske, 1987) include redefinitions of wall types and structure which improve efforts to classify and identify these species.

The question of priority of publication (Article 11) has not been an issue yet for VA mycorrhizal fungi. It was exercised by Gerdemann and Trappe (1974) when they re-established the name *Glomus* for chlamydosporic species in *Endogone*, a genus originally erected by Thaxter (1922). Few studies have resulted in synonymy between two taxa of VA mycorrhizal fungi. The only instance of this to date is the combination *G. epigaeum* (Daniels and Trappe, 1979) and *G. versiforme* (Berch and Fortin, 1983c). More often, species (Berch and Fortin, 1983c; Walker and Koske, 1987) or genera (Walker and Sanders, 1986) are segregated from taxa previously described in very broad terms. Walker (1987) has suggested synonymy between *Sclerocystis* and *Glomus*, but much has to be learned before such a move comes to fruition (Section IIA).

IV. IDENTIFICATION

Identification involves the practical usage of information collected from classifying and naming an organism. For VA mycorrhizal fungi, this involves recognizing a spore or group of spores collected from a field or pot culture soil. In geographic areas where no previous identifications have been, this may involve determining if a fungus belongs to an established taxon or differs sufficiently to be described as a new species. In West Virginia, for example, initial surveys of native VA mycorrhizal fungi resulted in four new species out of the first seven established in pot culture (Morton, 1986a; Morton and Walker, 1984).

Morphology always will exert primacy in classification and identification, mainly because the holotype specimen (see Section III) provides a physical entity to compare against the name and a written description. As a result, this will be the main focus of attention in this section. It is important to note that much of this discussion is based on data and observations from protologues and revisions of species descriptions, unless indicated otherwise.

Physical characteristics are important because they can be visualized universally with a good light microscope. Identification is achieved by comparing individuals using preserved specimens, species descriptions, illustrations, and keys. Much of the discontent and frustration in using morphological features comes from lack of exposure to a range of species, not enough time to develop "an eye" for recognizing each structure, and only vague concepts of how to evaluate variability among specimens. These obstacles are overcome only through self-education in specialty courses or workshops or through the use of learning aids. A book on methods applicable for mycorrhizal research (Schenck, 1982), a compilation of species descriptions under one cover accompanied by a "species guide" (Schenck and Perez, 1987), and a 2 x 2 slide set illustrating pertinent morphological characteristics for identification (Morton and Koske, in prep.) provide a start. Keys can be important tools in identifying an organism. Several large keys for VA mycorrhizal fungi have been published (Hall, 1984; Hall and Fish, 1979; Trappe, 1982). Smaller, but more manageable, keys synthesize current information on select groups of taxa (Gerdemann and Trappe, 1974; Koske and Walker, 1985; 1986; McGee, 1986; Nicolson and Schenck, 1979; Schenck and Smith, 1982; Walker and Trappe, 1981). The species guide of Schenck and Perez (1987) provides a practical approach in identifying a species. It supplies just enough information to reduce the number of choices to a manageable level, and then requires that the investigator carefully read the species descriptions to make a final decision. Even then, some descriptions (especially in *Glomus*) may be too vague to make a definitive choice. It is for this reason that voucher specimens are so important. They accomodate reappraisal of tentative identifications as more detailed information becomes known.

Most of our deficiencies in knowledge of taxonomic features are concentrated in *Glomus*. Many species need renewed study, especially those in which sporocarpic characteristics took precedence over spore morphology. A serious obstacle in this task is the inadequacy of type material for study. Species are difficult to redescribe accurately from preserved material because of modifications in spore morphology (see Section IVE). In many instances, new specimens will need to be retrieved from the original collection sites and examined [e.g. *G. fasciculatum* in Walker and Koske (1987)]. Even more important, new species should not be erected only from material stored in liquid preservatives. Spore characteristics of *Glomus hoi* (particularly color and wall morphology), for example, may not match those collected from the field because the fungus was described from specimens stored for a number of years in lactophenol (Berch and Trappe, 1985).

A. Organization of spores

Spores of VA mycorrhizal fungi first were thought to be arranged in loosely-formed clusters, randomly dispersed in a loose or dense hyphal network, or highly ordered around a hyphal plexus (Gerdemann and Trappe, 1974). Emphasis on sporocarpic forms gradually has been replaced by an awareness that many VA mycorrhizal fungi (70%) form ectocarpic spores singly on hyphae. Spores also can aggregate in animal remains (Rothwell and Victor, 1984), dead spores (Koske, 1984), dead seeds (Taber, 1982), insect husks (Rabatin and Rhodes, 1982), or in roots (Koske, 1985; Morton and Walker, 1984; Nicolson and Schenck, 1979; Schenck and Smith, 1982). In all but the last instance, spore aggregation is more likely a response to the physical environment than to inherent genetic mechanisms. *Acaulospora myriocarpa*, for example, sporulates in all of the above-mentioned habitats in South America (Schenck et al., 1986).

1. Aggregation of spores in roots

Most taxa forming spores in roots are in *Glomus*. Almost any fungus will produce an occasional spore in the root cortex. However, some species (*G. aggregatum*, *G. clarum*, *G. diaphanum*, *G. heterosporum*, *G. intraradices*, *G. manihotis*, *G. microaggregatum*) frequently form abundant intraradical aggregates of spores. Walker (pers. comm.) suggests that this habit is variable, but it has proven to be a consistent habit in isolates of *G. diaphanum* (Morton, 1985), *G. clarum*, and *G. intraradices* from soils in West Virginia and surrounding states (Morton, unpubl.). Abundance of ectocarpic spores was a more variable characteristic in different host-soil environments (Morton, 1985).

The life cycle of these fungi may be different from that of other VA mycorrhizal fungi in that the thin-walled vesicles either are transitory and replaced by intraradical spores or are precursors to spores (Gerdemann and Trappe, 1974; Morton, 1985). Identification of taxa with this type of life cycle may be important in the evaluation of inocula, since intraradical vesicles (or spores) can serve as propagules (Biermann and Linderman, 1983).

Species in several other genera can form sporocarps (*Sclerocystis coremioides*, B. Hetrick, pers. commun.), or spores (*E. schenckii*, *Scutellospora erythropa*, and *Scutellospora pellucida*) singly in roots. Stability of this phenomenon has not been

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Page 284 line 45 for *E.* read *Entrophospora*

assessed in these fungi, but the mechanism of formation obviously cannot involve vesicles as precursors in *Scutellospora*.

2. Aggregation of spores in sporocarps

Sporocarps often are large enough to be seen with the naked eye, enabling them to be collected by raking the upper soil surface (Gerdemann and Trappe, 1974). They also can be separated from soil debris by wet-sieving. In this review, sporocarps will be defined as aggregates of many spores with a loose or highly organized structure which do not separate into individual spores upon extraction from soil. A distinction between organized sporocarps (spores embedded in glebal hyphae) and clusters of spores eventually may be made once details of sporocarp development come to light.

Only in *Sclerocystis* are taxa obligately sporocarpic. Of nine species, only two are described as forming VAM in pot culture (*S. coremioides*, *S. rubiformis*). The sporocarpic habit of these taxa appears to be highly stable, based mostly on field-collected material from dissimilar habitats. Empirical data from pot culture experiments is lacking.

The sporocarpic habit is much more variable in *Glomus*. A large proportion of sporocarpic species (60%) have been collected only from field sites. For those species successfully propagated in pot cultures (40% of the taxa), spores may be formed only in sporocarps (e.g. *G. arborense*, *G. glomerulatum*, *G. pallidum*, *G. tenerum*), singly as well as in sporocarps (e.g. *G. macrocarpum*), or only singly (*G. microcarpum*). A continuum between single spores and sporocarps also may exist, as has been observed for *G. pansihalos* (Berch and Koske, 1986). Based on observations of *G. versiforme*, unspecified environmental conditions in different geographic locations appear to influence whether a fungus such forms sporocarps (Hetrick and Trappe, 1979) or single ectocarpic spores (Schenck, pers. comm.). Pot culture age can be an important factor in appearance of sporocarps, since these fruit bodies can take 4-12 months to develop (Gerdemann and Trappe, 1974; Smith and Schenck, 1985). All dimorphic species (*G. ambisporum*, *G. dimorphicum*, *G. heterosporum*) are described as having one morph which consistently forms sporocarps, but environmental stability under different ecological pressures has not been assessed empirically.

Of the two species considered sporocarpic in *Acaulospora*, only one (*A. myriocarpa*) has been propagated in pot culture. Variability in sporocarp development is not discussed in the protologue of this fungus, but it clearly is capable of forming single spores or tight clusters of spores in different niches (Schenck et al., 1986).

B. Sporocarp morphology

1. Arrangement of spores

Spores and hyphae are most highly ordered in sporocarps of *Sclerocystis*, where spores often are side-by-side in a single layer around a central hyphal plexus (Gerdemann and Trappe, 1974). The central core of thin-walled interwoven hyphae does not contain chlamydospores. This arrangement is observed in most species, but it is most pronounced in *S. clavispora*. Spores are more loosely organized in sporocarps of *S. coremioides* and *S. rubiformis*.

In *Glomus*, only the sporocarpic morph of *G. ambisporum* and *G. heterosporum* forms spores around a central hyphal plexus similar to that found in *Sclerocystis*. *Sclerocystis pachycaulis* suspicously resembles these dimorphic *Glomus* species based on the loose arrangement of spores and the presence of double-walled chlamydospores

(Wu and Chen, 1986). Unfortunately, this fungus was not grown in pot culture to examine this possibility.

Spores of most sporocarpic *Glomus* species are arranged randomly in interwoven hyphae (gleba). Spores of some species (*G. australe*, *G. fuegianum*, and *G. vesiculiferum*) are arranged in discrete clusters within the glebal hyphae. In other species (*G. pubescens*, *G. radiatum*, and *G. segmentatum*), spores radiate from the base of sporocarps.

Details of sporocarp development in *Acaulospora* are not known. Sporocarps of *A. myriocarpa* consist of tight clusters of spores which remain intact after the rigors of sieving and centrifugation during separation from soil (Schenck, pers. comm.). Sporocarps of *A. sporocarpia*, which contain spores embedded in a network of hyphae and sporiferous saccules, are described only from herbarium specimens (Berch, 1985). For this fungus, it is not known if sporocarp formation is genetically or environmentally induced.

2. Size of sporocarps

Sporocarps of all taxa in *Sclerocystis* are less than 1 mm in diameter, with those of *S. clavispora* being the largest (450-800 µm). *Glomus* species generally former larger sporocarps. Only sporocarps of *G. fasciculatum*, *G. microcarpum*, and *G. pansihalos* grade below one millimeter. Sporocarps of most *Glomus* species range between one and 20 mm. Sporocarp diameter appears to be a highly variable characteristic. *Glomus pallidum*, for example, forms sporocarps ranging from 1-25 mm in diameter (Hall, 1977).

Each of the two sporocarpic *Acaulospora* species are at opposite extremes. Sporocarps of *A. myriocarpa* generally are less than 1 mm; those of *A. sporocarpia* can be as large as 2.5 cm across.

3. Color of sporocarps

Color of sporocarps is determined most often by examining the fruit bodies under reflected light (e.g. a dissecting microscope). Trappe (1982) distinguishes between surface and internal color of sporocarps, since the two can be quite different. In *Glomus*, sporocarp surface coloration can range from white to brown; internal coloration can vary from white to black. Cut sporocarps with darkly pigmented interiors can be white on the surface because of crusting. For example, sporocarps with a white to grey surface (*G. caledonium*, *G. canadense*, *G. fragile*, *G. fuegianum*, *G. segmentatum*) usually are yellow to brown inside. Generally, the internal color of sporocarps is similar to the color of the embedded spores. Sporocarps grading between white to brown on the surface are brown (e.g. in *G. flavisporum*, *G. macrocarpum*, *G. invermaium*) or brownish-black (*G. melanosporum*) internally.

Most sporocarps of *Sclerocystis* species are brown, whether intact or cut. Surface coloration of *S. coremioides* and *S. dussii* varies from white to brown and it appears to be a function of age (white when young, brown when mature). The white surface coloration of *S. coccogena* sporocarps is attributable to numerous small hyaline to whitish spores intermixed within a surface pseudoperidium of hyphae.

Sporocarps of *A. myriocarpa* are hyaline, whereas those of *A. sporocarpia* dark brown to black. Both spores and sporocarps of *A. myriocarpa*, at least, are consistently hyaline among different isolates (Schenck et al., 1986).

4. Shape of sporocarps

Sporocarps of most *Sclerocystis* species are globose, subglobose, to ellipsoid in shape, although those of *S. coremioides*, *S. dussii*, and *S. sinuosa* are cushion-shaped (pulvinate). In *Glomus*, sporocarps are more irregularly-shaped, although they often are rounded along the upper surface. Some species have lobed sporocarps (*G. convolutum*, *G. radiatum*) or irregular surface aggregations (*G. boreale*, *G. pallidum*, *G. versiforme*, *G. vesiculiferum*). Sporocarps of several species have distinctive characteristics which merit weight in identification. *Glomus pubescens* sporocarps appear to be elevated on short stipes and those of *G. segmentatum* break into subpolygonal sections when teased apart. Morphological stability of these forms is unknown, however, since neither fungus has been cultured successfully.

5. Surface texture of sporocarps

Texture of sporocarps is governed somewhat by whether spores are exposed or covered with loose or tightly interwoven hyphae. The ends of spores are exposed in four *Sclerocystis* and seven *Glomus* species, giving the sporocarps a warty topography. Structures other than chlamydospores provide a warty surface in sporocarps of other species. For example, *S. dussii* has giant globose cells overlaying chlamydospores, and *G. aggregatum* and *G. vesiculiferum* have irregular-shaped and thin-walled swollen cells, respectively, on the surface of sporocarps. These mysterious structures are not found consistently on sporocarps of *G. vesiculiferum* formed in pot culture (Berch and Fortin, 1984b).

Sporocarps of other taxa with exposed spores on the surface can appear cottony from interspersed hyphal wefts (e.g. *G. macrocarpum*, *G. melanosporum*, *G. pallidum*). Most fungi with loosely interwoven hyphae encasing clustered spores have a cottony or felty texture on the surface (three *Sclerocystis* and eleven *Glomus* species).

6. The peridium of sporocarps

Ainsworth (1971) defines a peridium as the wall of a sporangium or other fruit body. For most VA mycorrhizal fungi, a hyphal network covering small clusters of spores (e.g. *G. mosseae*, *G. monosporum*) or sporocarps has been interpreted as a peridium. Interwoven hyphae encircling individual spores has been termed a hyphal mantle (e.g. in *G. convolutum* and *G. tortuosum*), although distinctions in origin and development are not clear cut. Walker (1983) includes the peridium as a wall type, but this interpretation appears to be one of convenience only. The peridium covering sporocarps of *Sclerocystis* and *Glomus* species consists of hyphae which may be tightly (*S. sinuosa*, *G. canadense*, *G. fuegianum*, *G. segmentatum*) to loosely interwoven (e.g. *G. flavisporum*, *G. pulvinatum*, *G. radiatum*). The peridium covering sporocarps of *G. pubescens* is distinctive in that erect hyphal tips are exposed amongst the tangled hyphae. In other taxa, the peridium may be present, absent, or patchy over the sporocarp surface (*G. boreale*, *G. convolutum*, *G. macrocarpum*). Sporocarps of *G. microcarpum* may be without a peridium when small, but the peridium often is present in larger sporocarps (those approaching 5 mm) (Berch and Fortin, 1984a). Size, and possibly age, of sporocarps are important factors affecting peridium development. Three *Sclerocystis*, seven *Glomus*, and two *Acaulospora* species do not form a peridium enclosing sporocarps. *Glomus convolutum* is distinctive in that each spore is covered with a hyphal mantle, but the sporocarp lacks a peridium.

7. Glebal hyphae of sporocarps

The hyphae constituting the matrix for many sporocarpic taxa in *Glomus* and *Sclerocystis* have not been described in any great detail. The hyphae of *G. vesiculiferum* are unique, with numerous septa up to 10 um in thickness (Berch and Fortin, 1984b). With the exception of *G. melanosporum*, most *Glomus* species (e.g. *G. aggregatum*, *G. invermaium*, *G. fasciculatum*) do not have extensive glebal hyphae.

8. Substances exuding from sporocarps

Sporocarps of some species (*G. macrocarpum*, *G. melanosporum*) exude a latex when cut. This material apparently originates from the lumen of spores (Gerdemann and Trappe, 1974). *Glomus convolutum*, on the other hand, exudes a yellow oil from cut hyphae and spores. These fungi appear to possess unique physio-chemical properties.

C. Morphology of intact spores

With care, different taxa of VA mycorrhizal fungi often can be separated visually under a low power dissecting microscope after spores are extracted from a soil. Individual spores can be separated by similarities or differences in color, size, and shape. Even so, accurate identification of each fungus still requires careful examination of a number of spores under a light microscope, often at high magnifications.

1. Color of spores

Differences in spore color are easily discerned under a dissecting microscope. As a result, color has received undue emphasis in identification. Despite its visual prominence, spore color is a highly variable characteristic (Fig. 4). Color is influenced by the manner in which light passes from the object to the viewer. In many species descriptions, it is not clear whether color is determined from reflected light (e.g. spores viewed through a dissecting microscope) or from transmitted light (e.g spores viewed through a light microscope). Unless specified in protologues, the former is assumed in this review.

Color differences among species may be due either to pigments in spore walls or pigments in the cytplasmic contents of spores. The latter has been reported in only a few species (*Gigaspora gigantea*, *Glomus convolutum*). The internal contents of *G. gigantea* spores are greenish-yellow to yellow-green, whereas the spore walls are hyaline to pale yellow. Spores can grade to dark brown in both field and pot culture material (Koske and Morton, unpubl.), probably because of oxidation of contents during senescence or as a result of hyperparasitic activity. Spores of *G. convolutum* are a deep yellow from pigments in oil globules within the spore (Gerdemann and Trappe, 1974). Stability of this characteristic is not known because this fungus never has been propagated in pot culture.

In taxa which form white (translucent) or hyaline (transparent) spores, spore color rarely turns darker than a pale brown (Fig. 4). *Glomus fecundisporum* is the only exception in the literature, being described as occasionally forming brown to black spores in culture (Schenck and Smith, 1982). It is not known if this extreme gradation in color is a pigment change in the spore wall (possibly genetic) or in the cytoplasm (possibly parasitism or senescence). It should be noted that the spores of many species reported as hyaline actually are white. Few spores consistently are transparent, simply because internal oil globules scatter reflected light and render the spores opaque.

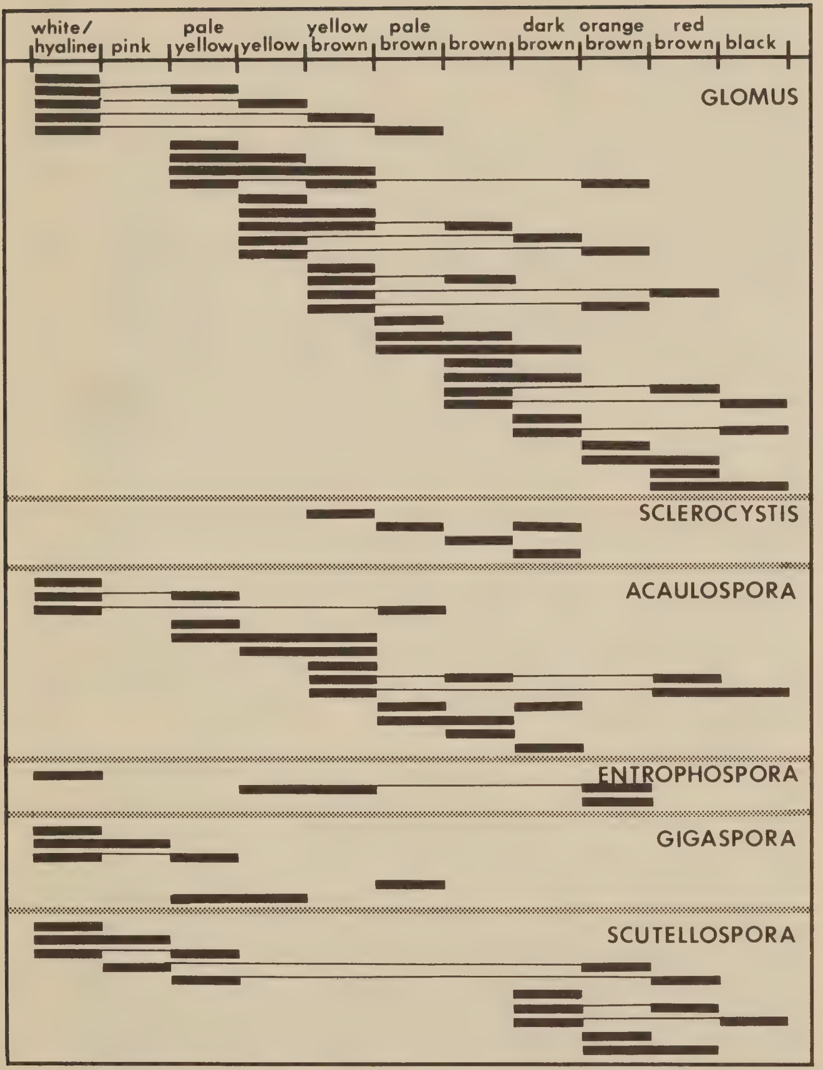


Fig. 4. The range in color of spores in taxa of all genera of VA mycorrhizal fungi. Thickened bars indicate colors reported in species descriptions. Taxa with the same range in spore color are pooled on the same line. The combinations grey-brown or pale yellow with greenish tinge are not included.

Spores which are pale yellow at their lightest rarely darken to more than yellow-brown, although those of *G. aggregatum, G. pustulatum,* and *Scutellospora verrucosa* can grade to orange-brown. Yellow or yellow-brown spores at their lightest darken at most to an orange-brown or red-brown color (e.g. *G. formosanum*, *G. pansihalos*, *A. laevis*, *A. spinosa*, *Scutellospora heterogama*). Only *A. tuberculata* forms spores with a broad range in color from yellow-brown to reddish-black. Most species with pale brown or brown spores rarely take on additional pigments. These spores usually just grade into a darker brown color (e.g. *G. heterosporum*, *G. invermaium*, *A. scrobiculata*). Spores which are never lighter than a dark brown spores grade into darker shades, sometimes picking up yellow (to make orange) and red pigments. Going from dark to light, taxa with reddish-black or black spores rarely form spores lighter than a dark yellow-brown (e.g. *A. tuberculata*).

Significant trends in gradation in spore color are evident at the genus level (Fig. 4). Spores of *Glomus*, *Acaulospora*, and *Scutellospora* species range in color from hyaline to black. Spores of *Entrophospora* exhibit similar variability, but each of the three described species has a distinct color range. Spores of *Sclerocystis* and *Gigaspora* have a more restricted range of color gradation, being consistently different shades of brown in the former and hyaline to pale yellow-brown in the latter.

2. Size of spores

Spore diameter often is reported in species descriptions as a range from smallest to largest. Sometimes this range encompasses a "majority" of spores, with rare extremes noted in parentheses. In other instances, the range is reported as a mean value, with extremes noted in parentheses. Mean or range values cannot be used to make direct comparisons among species because of this lack of standardization. Worse, the precision of these measurements cannot be evaluated because numbers of spores rarely are documented. A wide range in spore size could reflect either a large sample population or genetic variability. Conversely, a narrow range could mean that only a few spores were examined.

To make some effort at comparisons among VA mycorrhizal fungi in this review, spore size is calculated as a midpoint value (mid-diam) between maximum and minimum values (Fig. 5). The extent of variability in spore size is judged by the difference between maximum and minimum values (Fig. 6). Spore mid-diam of VA mycorrhizal fungi generally falls into two broad groups. One group includes most *Glomus*, *Sclerocystis*, *Acaulospora*, and *Entrophospora* species, where 90%, 67%, 82%, and 100% of the taxa in each genus, respectively, form spores with mid-diams between 50 and 250 µm (Fig. 5). For most of these species, the extent of variation in mid-diam is less than 100 µm (Fig. 6). Variability is greatest in larger-spored species. For example, *G. caledonium* is the largest-spored *Glomus* (mid-diam of 256 µm), and spores range from 124 to 391 µm. Similarly, *A. laevis* spores (mid-diam of 320 µm) vary from 119 to 520 µm. The other group encompasses most *Gigaspora* and *Scutellospora* species, which have spore mid-diams which exceed 300 µm. The extent of variation in these taxa, despite large spore size, is mostly less than 100 µm. These data indicate considerable interspecific and intergeneric overlap among taxa in each of the two groups. Despite the possibility of errors in interpretation because of non-statistical comparisons, most evidence indicates that spore diameter should not be weighted heavily in identification.

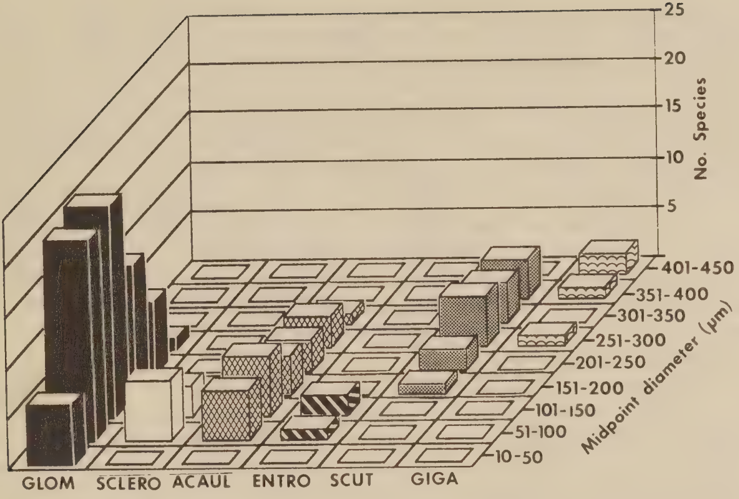


Fig. 5. The diameter of spores in taxa of all genera of VA mycorrhizal fungi, calculated as the midpoint between reported maximum and minimum values (Max. diam. - Min. diam./2 + Min. diam.). GLOM = *Glomus*, SCLER = *Sclerocystis*, ACAUL = *Acaulospora*, ENTRO = *Entrophospora*, SCUT = *Scutellospora*, and GIGA = *Gigaspora*.

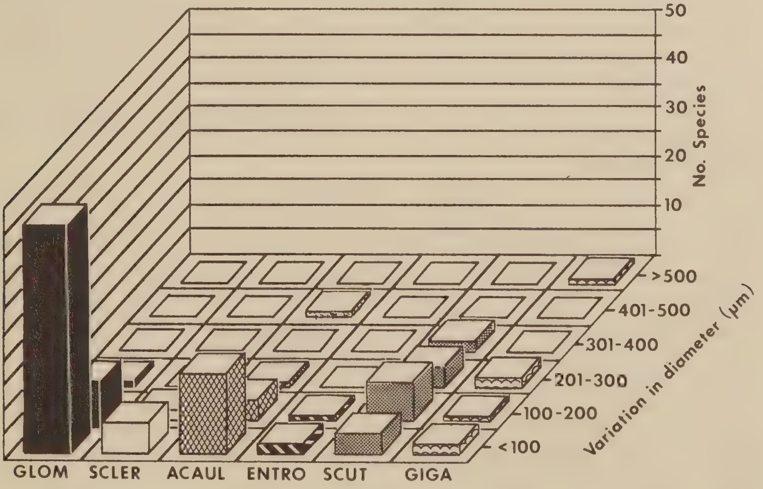


Fig. 6. Variation in spore diameter in taxa of all genera of VA mycorrhizal fungi, calculated as the difference between reported maximum and minimum values (Max. diam. - Min. diam.). See **Fig. 5** for explanation of genus abbreviations.

Spore size may have greater significance in showing relationships among taxa. A significant relationship appears to exist between spore size and sporocarpic habit. Large-spored genera (*Gigaspora* and *Scutellospora*) form spores only individually. All other genera (excluding *Entrophospora* for which only 3 species are described) have sporocarpic members. Considering only those fungi with a maximum spore diameter of less than 125 µm (23 *Glomus*, 6 *Sclerocystis*, 5 *Acaulospora*, and one *Entrophospora* species), 80% of these taxa are obligately or facultatively sporocarpic. Still, some small-spored species (e.g. *A. trappei*) show no evidence of forming sporocarps.

More detailed and precise analyses of such relationships might eventually be possible if new (or revised) descriptions of species include data on size distribution in spore population. Such an approach has been taken for only a few species (Berch and Koske, 1986; Koske et al., 1986; Schenck et al., 1986), providing a much clearer and concise picture of intra- and inter-specific variation.

4. Density of spores

Spore density can be determined indirectly by the tendency of spores to sink or float in different solvents. The adhesion-flotation (Sutton and Barron, 1972) and flotation-bubbling (Furlan and Fortin, 1975) systems for separating spores from soil debris were developed to take advantage of this behavior. Unfortunately, these methods lacked the flexibility to manage soils or VA mycorrhizal fungi with widely differing physical properties.

Spore density has not been used often as a criterion for separating species. Most species appear to have a similar tendency of sinking in water or remaining suspended in a solvent with higher specific gravity (e.g. sucrose or glycerol). However, these assumptions may disguise real differences either not noticed or ignored. Distinct differences among a few species can be found in the literature. Rose et al. (1979) indicate that a soil suspension containing *G. gerdemannii* must be decanted into sieves in less than one minute after stirring because spores sink very quickly. At the other extreme, spores of *G. occultum* float in 10% sucrose for several minutes before sinking and thus can be separated easily from other species (Morton, 1985). The major difficulty with this fungus is separating spores from organic debris, which also floats.

3. Shape of spores

Spore shape also is a highly variable characteristic (Fig. 7), probably because it is easily affected by the physical environment in which the spores form. Small to medium-sized spores without thick rigid walls, for example, often are ellipsoid when formed in root cortical tissue (e.g. *G. intraradices*, *G. diaphanum*, *Scutellospora pellucida*). Larger, thicker-walled intraradical spores are more likely to remain globose or subglobose (e.g. *G. clarum*, *G. manihotis*). In *Sclerocystis*, which is consistently sporocarpic, none of the taxa form globose spores. Only four species (*S. coccogena*, *S. coremioides*, *S. pachycaulis*, *S. rubiformis*) produce spores which are subglobose to ellipsoid. Oblong to clavate spores are formed in *Sclerocystis* species with highly-ordered sporocarps. In several species (*S. dussii*, *S. sinuosa*) some spores in the sporocarps can be obovoid or ellipsoid. Clavate spores are not formed in any other taxa of VA mycorrhizal fungi. Less than 10% of the taxa in *Glomus* grade from ovoid or obovoid to irregular or oblong, and those that do are sporocarpic (e.g. *G. boreale*, *G. flavisporum*, *G. radiatum*).

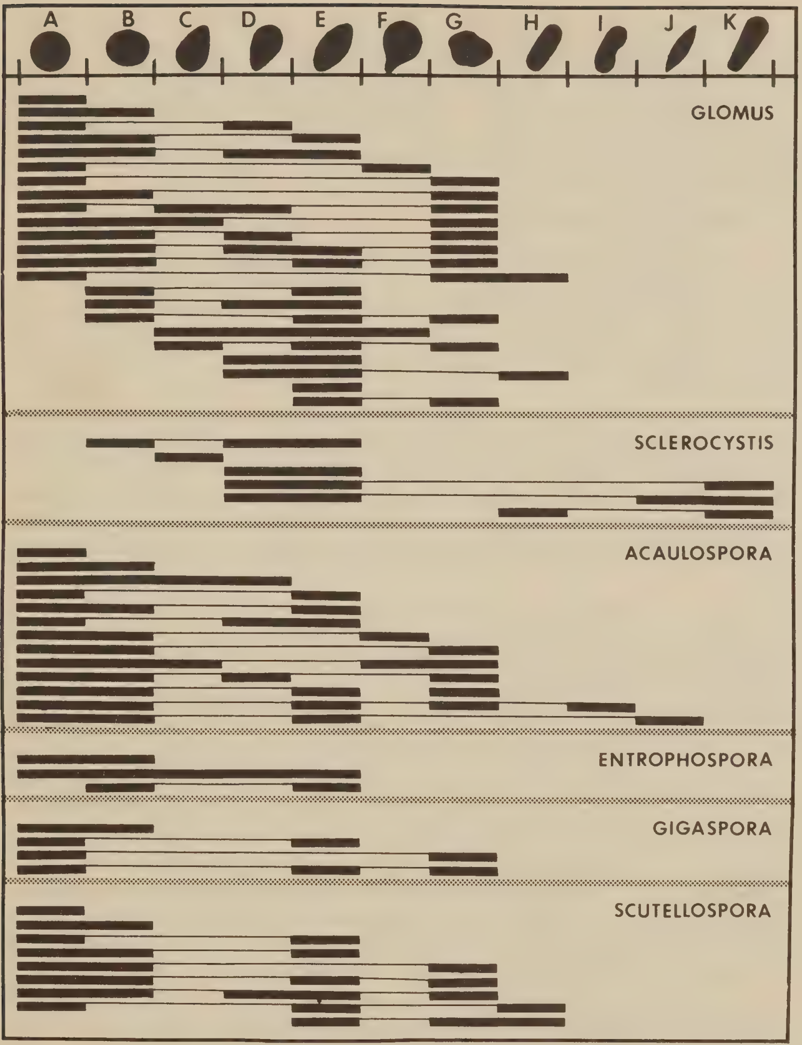


Fig. 7. The range in shape of spores in taxa of all genera of VA mycorrhizal fungi. A = globose, B = subglobose, C = ovoid, D = obovoid, E = ellipsoid, F = pyriform, G = irregular, H = oblong, I = reniform, J = fusiform, K = clavate. Thickened bars indicate shapes reported in species descriptions. Taxa with the same range in spore shape are pooled on the same line.

With the exception of *Sclerocystis*, most taxa produce at least some spores which are globose to subglobose. Only globose to subglobose spores are formed by 44%, 27%, and 36% of the taxa in *Glomus*, *Acaulospora*, and *Gigaspora*, respectively.

Few species in *Acaulospora*, *Gigaspora*, or *Scutellospora* form a majority of spores which are elongated (unless they are formed in roots, e.g. *S. pellucida*). Some spores of *A. sporocarpia* can assume a pyriform shape, but this may be due to constraints of sporocarp development.

D. Spore wall structure

The spore wall, more than any other morphological character, defines a fungus. Wall structure provides important clues about vegetative growth, mode of reproduction, events in ontogeny of spores, and survival mechanisms (Bartnicki-Garcia, 1968). From the discussion in Section IIA, it is clear that wall structure must be examined in detail to determine the type of spores produced and how they form.

Fungal cell walls consist mostly (80-90%) of polysaccharides, the remainder being protein and lipid. Chitin and cellulose comprise the microfibrillar backbone of cell walls. Major differences in structural components rarely are observed in taxa with similar spore morphology (Bartnicki-Garcia, 1968). Chitosan, a poorly acetylated poly-glucosamine, is a characteristic component of cell walls in Zygomycetous fungi. Possibly, this polymer fulfills the structural role normally relegated to glucans in other fungi.

Wall structure always has been a consideration in classification and identification of VA mycorrhizal fungi (Gerdemann and Trappe, 1974; Mosse and Bowen, 1968; Trappe, 1982), but it was weighted equal to or less than other more variable characteristics. The complexity of wall structure in VA mycorrhizal fungi was not recognized generally until descriptions of *Acaulospora* and *Scutellospora* began appearing in the literature. Then, definition of separate wall types became essential to standardize terminology and provide a focal point from which investigators could recognize old and new differences among taxa (Walker, 1983). This wall terminology now is accepted by most workers, although it has been subject to some criticism. Berch (1986) has proposed that "wall layers" be substituted in place of "walls". She reasons that without knowledge of the origin of each structural component forming the spore, differences among these components cannot be identified at this time. Her argument is valid, but it offers no additional insights into our present knowledge of wall structure. Such changes in terminology should be postponed until more concrete information is available on the development of the different wall types.

In order to examine spore wall structure, intact spores must be extracted from soil, mounted on glass microscope slides, and broken under pressure. Spores from field-collected soil must be carefully chosen to exclude specimens which have undergone changes in wall structure because of hyperparasitism. For example, inner walls can disappear (Walker et al., 1984) and outer walls may become pitted (Bhattacharjee et al., 1982) from such activity. This is less of a problem in pot cultures employing sterilized or pasteurized substrates. A source of variation in wall structure of spores from pot cultures is age. Immature spores can constitute a major portion of the population in pot cultures less than 2-3 months old, especially those started from only one to several spores.

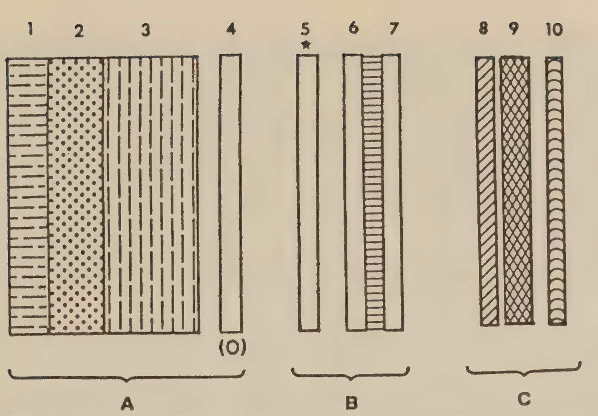


Fig. 8. Murograph of wall type, number, group, and position in a VA mycorrhizal fungus spore (from Berch and Koske, 1986; Morton, 1986; Walker, 1983; Walker, 1986). (O) = ornamented surface, * = difficult to see. Lines connecting two walls depict a cementing layer. Walls are numbered consecutively from the outer to inner surface. 1 = expanding, 2 = evanescent, 3 = laminated, 4-7 = unit, 8 = membranous, 9 = coriaceous, 10 = amorphous walls. Each wall group is bracketed in parentheses with consecutive letters from outer to inner surface.

With emphasis on individual components of spore walls in recent years, characteristics of the intact "composite" wall in unbroken or lightly broken spores no longer are reported in species descriptions. Color and thickness of the composite wall undoubtedly overlap among taxa and thus would not have much weight in identification, but these details would provide the working scientist with a more realistic picture of the intact spore wall before it is broken apart and distorted.

1. Wall type

Wall types are identified strictly by their appearance in intact or broken spores under the light microscope. Ontogeny or function currently are not part of wall definitions, but eventually this information will be needed to stabilize terminology. Walker (1983) first defined the evanescent, unit, laminated, and membranous wall types. Since then, three new wall types have been described: the expanding wall (Berch and Koske, 1986), the amorphous wall (Morton, 1986), and the coriaceous wall (Walker, 1986).

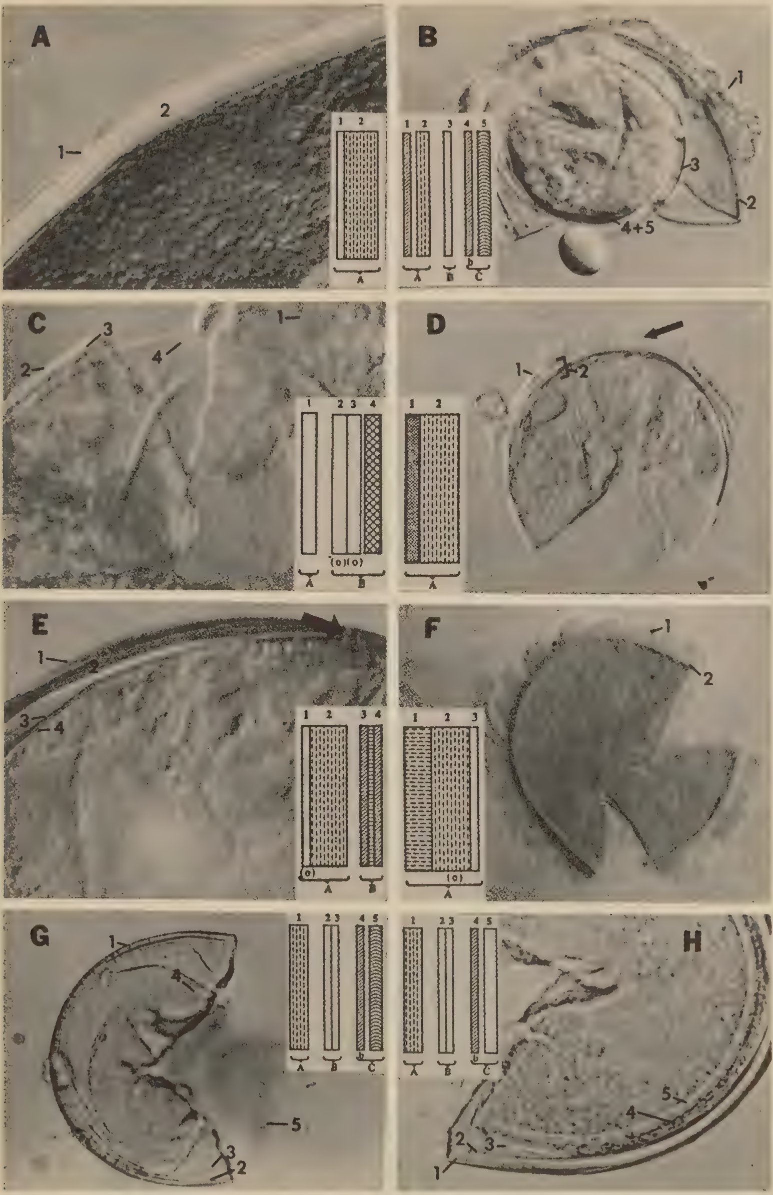
Despite recent advances in delimiting different wall types, the spore wall structure of many species described prior to (and sometimes after) 1983 are difficult to interpret because of scant detail. Koske and Walker (1985; 1986) have redescribed wall structure in a number of *Scutellospora* species, but wall types still are not defined well in most *Sclerocystis*, 22 *Glomus*, four *Acaulospora*, one *Gigaspora*, and four *Scutellospora* species. Murographic representations of wall types (Walker, 1983) are illustrated in Fig. 8. The murograph of the "expanding" wall has been revised (Schenck and Perez, 1987) from that proposed in the description of *Glomus pansihalos* (Berch and Koske, 1986). Walker (1986) also proposes use of a "muronym" to aid in describing wall information for input into a computerized database or key. It has proven very useful in the INVAM species guide to summarize succinctly the type and arrangement of walls (Schenck and Perez, 1987).

The laminated wall (Fig. 9A) is defined as a rigid wall composed of fused multiple layers (referred to as "laminae") formed successively as the spore matures. It breaks easily when pressure is applied to the spore. The laminae of a wall usually can be detected in most taxa because of differences in refraction with transmitted light, especially when spores are mounted in water or glycerin. In pigmented spores, the laminated wall usually is colored. The function of this wall probably is mainly to provide structural integrity to the spore and to resist dessication and predation.

The unit wall (Fig. 9A-C) also is a rigid wall, but it is formed as a singly layer which fractures easily when pressure is applied to a spore. Most unit walls range from 0.5-3 µm thick, but sometimes they can be less than 0.5 µm (*A. scrobiculata*, *S. erythropa*, *S. weresubiae*) or up to 6 µm thick (*A. appendicula*) (Fig. 9C). So far, no VA mycorrhizal fungus has been reported with only a single unit wall enclosing spore contents. When the unit wall provides structural integrity for the spore (*G. occultum*, *G. aggregatum*, *G. microaggregatum*, *A. appendicula*, *A. longula*, *A. morrowae*, *A. myriocarpa*, *A. spinosa*, and *E. schenckii*) two or more are found together and they often are pigmented. When the unit wall does not provide a structural function (e.g. thin outermost walls or inner walls), it most often is hyaline.

The evanescent wall (Fig. 9D) appears as a unit wall in young spores, but then it breaks down or sloughs as a spore matures. This wall type is much more difficult to evaluate because of its transitory nature. In field-collected material, adhering debris may give the impression of a degrading wall. Only when some spores in a population possess an intact wall in place of the roughened outer surface is a proper identification possible. Propagation of spores in pot culture provide a valuable means of determining the presence or absence of an evanescent wall in spores of different physiological maturity. A rough or granular layer on the outer surface of spores does not always indicate an evanescent wall. If such a granular layer is consistent on all spores in a population, especially in pot culture, then it is not evanescent. This has been observed on spores of two undescribed species in West Virginia maintained in successive pot cultures for three years (Morton, unpubl.). This characteristic may represent a different wall type, but more likely it is indicative of ornamentation on a laminated wall. The evanescent wall has been described in spores of *G. albidum*, *G. ambisporum*, *G. dimorphicum*, *G. etunicatum*, *G. gerdemannii*, *G. heterosporum*, *G. hoi*, *G. tenebrosum*, *G. versiforme*, *A. delicata*, *A. longula*, and *A. nicolsonii*. None of the taxa in *Gigaspora*

Fig. 9. Wall types in broken spores of VA mycorrhizal fungi. Murographs (see **Fig. 8** for explanation of patterns) indicate the wall structure most often observed. A. *Gigaspora gigantea* (NI) (380X). B. *Acaulospora rugosa* with two innermost walls unbroken (NI) (320X). C. *Acaulospora appendicula* (NI) (240X). D. *Glomus intraradices* with arrow pointing to breakdown of outer wall (NI) (320X). E. *Scutellospora heterogama* with germ tube emerging at arrow (NI) (500X). F. *Glomus pansihalos* (NI) (250X). G. *Acaulospora dilatata* freshly mounted in PVA and Melzer's reagent, but photographed from a 2-year-old slide (300X). H. *A. dilatata* preserved for 100 days in 5% formalin and mounted in PVA (NI) (440X).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or *Scutellospora* form spores with an evanescent wall, possibly indicating significant differences in spore ontogeny.

The membranous wall (Fig. 9B, E) is a thin, flexible wall formed as a single layer which often wrinkles or collapses in crushed spores. It usually ranges from 0.5 to 2 µm thick, but it can thicken up to 3 µm (*A. foveata*, *A. tuberculata*). The membranous wall usually is hyaline. It has been reported yellow only in the sporocarpic morph of *Glomus dimorphicum*, but this may be an artifact of viewing the adherent membranous wall through the outer yellow laminated wall. When a membranous wall is part of an inner wall group, it does not fracture readily in spores lightly broken (Fig. 9B). This phenomenon has led to the term "endospore" being applied to an innermost membranous wall (Ferrer and Herrera, 1981). The membranous wall is found in spores of all genera of VA mycorrhizal fungi except *Sclerocystis*. It is omnipresent in spores of *Scutellospora* and *Acaulospora* species.

The coriaceous wall (Fig. 9C) is a thick, hyaline, flexible wall formed as a single layer. Like the membranous wall, it does not fracture easily in lightly broken spores. This wall type is termed "coriaceous" because of its leathery appearance, the outer surface appearing wrinkled in a hypertonic mountant. Unfortunately, this wrinkling characteristic is not a consistent feature. Walker (pers. comm.) indicates that this wall type was erected to represent flexible walls which were thicker than the membranous wall. The coriaceous wall has been described only in *S. dipapillosa* and *S. weresubeae* to date, but it has gone unrecognized in *A. appendicula* (Fig. 9C) and *S. pellucida* (Fig. 11). Several *Scutellospora* species currently are being described which have a coriaceous wall adjacent to an inner amorphous wall (Morton and Koske, 1988; Walker, pers. comm.).

The membranous and coriaceous walls overlap considerably in thickness, which is the main criterion to separate to two wall types. This overlap even is noted in the description of *G. globiferum* (Koske and Walker, 1986). Recognition of each wall type as distinct entities becomes a problem that will be resolved only after variability in thickness of each wall type is assessed and the limits defined. However, this problem would become academic if coriaceous walls could be shown to possess a similar function to membranous walls (e.g. associated with germination shield formation). Both wall types then would constitute a functional complex which could be defined with a single term (e.g. "flexible" or "pliable" walls).

The "expanding" wall (Fig. 9F) is a hyaline unit wall which expands markedly (20-100 µm) when exposed to acidic mountants (e.g. PVL, PVA, lactophenol). The expanding wall has been described only in *G. pansihalos* so far (Berch and Koske, 1986). The wall often forms distinctive hyaline to pale yellow roughened radial columns in the expanded halo surrounding the spore. The stability of the morphological changes in an acidic environment is not known, since *G. pansihalos* has not been propagated in pot culture and studied empirically.

The amorphous wall (Fig. 9G) is not easily defined, because of changing characteristics in different chemical environments. In any mountant with a pH less than 2.0 (e.g. PVA, PVL, lactophenol), this wall is plastic (Morton, 1986b). In nonacidic environments such as water or glycerol (liquid or jelly), the wall appears as a rigid unit wall. Like the membranous and coriaceous wall, the amorphous wall does not fracture in lightly broken spores (Fig. 9B). It has been mistaken for a membranous wall (*A. morrowae*, *E. colombiana*), but this is not surprising in view of its appearance in squashed spores. The outer boundary of the amorphous wall is of a similar refractive index to PVL or PVA, making it difficult to see without Nomarski Interference optics (Fig. 9G). The inner surface is highly wrinkled, thus mimicing the appearance of a highly convoluted membranous wall. The gap between inner and outer surface is transparent and can be mistaken for a space between two walls. These observational difficulties are overcome in Melzer's reagent, where the amorphous wall stains a dark reddish-purple. To see plasticity in the wall (expansion beyond the broken outer wall of a spore), the spore must be crushed twice: the first time to break the spore and allow infiltration of the mounting medium (thus effecting the chemical change in wall structure) and a second time (usually within one minute) to "push" out the wall. The amorphous wall also can be identified by its transformation from a plastic wall in fresh spores to a rigid unit wall in specimens preserved for longer than three months (Fig. 9H).

The amorphous wall has been found so far in all genera of VA mycorrhizal fungi except *Glomus*, *Gigaspora*, and *Sclerocystis*. Taxa with this wall include: *A. dilatata*, *A. lacunosa*, *A. morrowae*, *A. lacunosa*, *E. colombiana*, *Scutellospora pellucida*. The amount of plasticity depends on the amount of wall material deposited in what appears to be a genetically determined characteristic of each taxon. The amount of wall material can be measured indirectly in preserved spores. For example, *A. dilatata* has a highly plastic amorphous wall (extends up to 200 µm beyond the spore) which measures up to 4 um thick in preserved material (Morton, 1986a). The amorphous wall rarely extends more than 50 µm from crushed spores of *A. rugosa*, and it is less than 2 um thick in fixed specimens.

2. Wall ornamentation

Laminated, unit, and membranous walls may possess surface topography or structures which give them an ornamented appearance. Ornamentations have not been described on walls of *Gigaspora* or *Sclerocystis* spores. Usually it is the laminated wall of spores in *Glomus* which is ornamented (*G. pustulatum* and *G. ambisporum* being the exceptions). In *Acaulospora*, either laminated or unit walls are ornamented. In *Scutellospora*, it is the thin outer unit walls of spores which are ornamented. An exception is *S. nigra*, which has a complex ornamented wall structure that is in need of redescription using current terminology.

The laminated wall may be ornamented with rounded projections (*G. multicaule*), knobs (*G. scintillans*), crowded spines with (*E. infrequens*) or without (*G. botryoides*, *G. halonatum*, *G. monosporum*) pitted tips, tubercles (*G. tenebrosum*), hemispherical warts (*G. pansihalos*), and an alveolate reticulum overlaying echinulations (*A. elegans*). The laminated wall also may be pitted, with the pits being puncticulate (*A. dilatata*), round-bottomed with ridges (*A. foveata*, *A. scrobiculata*), or round-bottomed with raised edges (*A. lacunosa*).

The unit wall may be ornamented with echinulations consisting of polygonal spines (*A. spinosa*), pustules (*G. pustulatum*), tubercles (*A.tuberculata*), tooth-shaped projections (*A. denticulata*), colliculate projections (*A. appendicula*) or a polygonal reticulum of ridges (*A. bireticulata*), low warts with tendril-like projections (*S. dipapillosa*), patch-like warts with angular margins (*S. coralloidea*), and closely-packed warts with rounded tips either less than 2 µm (*S. heterogama*, *S. persica*, *S. verrucosa*) or greater than 2 µm (*S. gregaria*) in diameter. Only one species (the sporocarpic morph of *G. ambisporum*) has an evanescent wall which, before sloughing, is covered with an ordered arrangement of hexagonal plates.

Considerable variation may exist in the degree of ornamentation on outer walls, although this is not well documented. Rounded projections are not present on the outer wall of all spores of *G. tenebrosum* (Berch and Fortin, 1983c) and crater-like pits on the outer wall of *A. lacunosa* vary from many to few in number, depending on the isolate (Morton, unpubl.)

An inner membranous wall ornamented with granular excrescences (giving it a "beaded" appearance) has been described in spores of *A. delicata*, *A. dilatata*, *A. lacunosa*, *A. laevis*, *A. mellea*, *A. rugosa*, *A. scrobiculata*, and *E. colombiana* (Fig. 9G-H). This type of ornamentation has not been observed on flexible inner walls of either *Glomus* or *Scutellospora* species. So far, it appears to be a consistent feature as long as mountants are used with a minimum amount of phenol (see Section IVE).

3. Number of walls

The number of spore walls vary among taxa in any genus of VA mycorrhizal fungi (Fig. 10). In general, spores of *Glomus*, *Sclerocystis*, and *Gigaspora* species usually have only 1-2 walls (80%, 100%, and 100% of taxa in each genus, respectively). More than 3 walls are present in spores of 75%, 90%, and 67% of taxa in *Acaulospora*, *Scutellospora*, and *Entrophospora*, respectively. These additional walls most often are flexible. For example, all species with 4-walled spores have a membranous innermost wall. *Acaulospora appendicula* is the exception, and it forms spores with a flexible coriaceous inner wall. Taxa forming spores with 5-6 walls most often either have a membranous or an amorphous inner wall. *Glomus gerdemannii* is the only exception, but the wall structure of this fungus needs to be reevaluated.

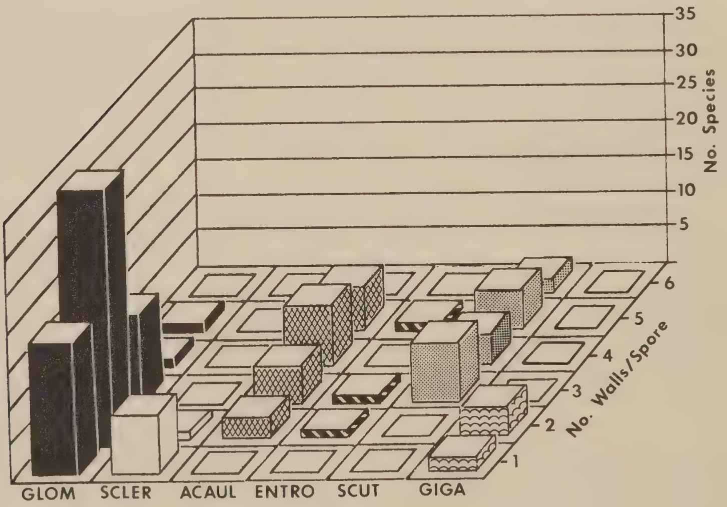

Fig. 10. The number of walls in spores of taxa in all genera of VA mycorrhizal fungi. GLOM = *Glomus*, SCLER = *Sclerocystis*, ACAUL = *Acaulospora*, ENTRO = *Entrophospora*, SCUT = *Scutellospora*, and GIGA = *Gigaspora*.

The number of walls is remarkably stable for most VA mycorrhizal fungi, being documented in *G. occultum* and *G. diaphanum* (Morton, 1985) and inferred from observations of other taxa in disparate habitats. *Glomus aggregatum* is an exception, with spores having one or two laminated walls. However, spore development also is highly variable in this fungus (Koske, 1985). Spores of *G. clarum*, *G. manihotis*, and *G. intraradices* can have a variable number (1-4) of yellow to yellow-brown inner walls which look like unit walls, but these most likely are laminae of a single laminated wall easily separated upon crushing (Fig. 9D).

4. Wall groups

A wall group is defined by Walker (1983) as an aggregation of walls which remain in proximity to each other after a spore is crushed. Such wall arrangements can be diagnostic and also are fairly consistent as long as spores are fresh, mounted in the same medium, and broken with an equivalent amount of pressure. The manner and degree spores are crushed accounts for most of the variability.

Wall groups are best depicted in murographs (Fig. 8). In a number of descriptions, wall groups often have been treated as individual walls. This is best exemplified by comparing protologues and revised descriptions of *S. calospora*, *S. heterogama*, *S. pellucida*. All three species originally were described as having two walls: an outer rigid wall and an inner flexible wall (Gerdemann and Trappe, 1974; Nicolson and Gerdemann, 1968; Nicolson and Schenck, 1979) (Fig. 11A). Actually, spores of each fungus have two wall groups, with 4, 4, and 6 walls in *S. calospora*, *S. heterogama*, and *S. pellucida*, respectively (Koske and Walker, 1985; 1986) (Fig. 11B). Similarly , *E. colombiana* was described by Schenck et al. (1984) as having "2-3 separable walls". Using current terminology, spores of this fungus have 3 wall groups encompassing 5 individual walls. These differences in interpretation must be kept in

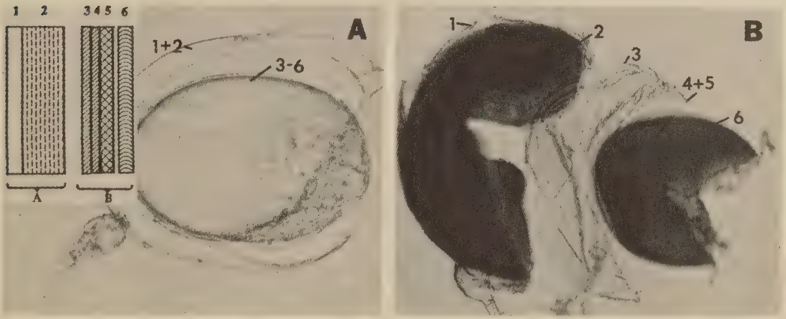

Fig. 11. Spores of *Scutellospora pellucida*. A. Spore broken lightly to show walls separated into two groups; the murograph (see **Fig. 8** for explanation of patterns and labels) has been modified with the development of the coriaceous wall concept (Morton and Koske, unpubl.)(NI) (165X). B. Spore mounted in PVA with Melzer's reagent and crushed more vigorously; the amorphous wall 6 is attached to wall 5, but this connection is obscured by the focal plane (NI) (140X).

mind when trying to compare an unknown fungus with published descriptions. Gibson (1985), for example, interpreted *S. heterogama* and *S. pellucida* as having two walls instead of two wall groups, a perception which extended to the ultrastructural level. The absence of clear distinctions between individual walls under the electron microscope is surprising, but the process of fixation may have obscured these details. Clearly, ultrastructural studies of spore wall structure must also be accompanied by light microscopic observations to detect such problems.

5. Position of walls

Walls are numbered in murographs to indicate the position of one wall relative to another. While considerable diversity exists among species of VA mycorrhizal fungi, several consistent trends are evident. Spores of all taxa have at least one wall which provides structural integrity (B in Fig. 12). This usually is either a laminated wall or two or more unit walls, the former being most common. Outside this structural wall, spores may possess a peridium surrounding spores in sporocarps (see Section IVB), another laminated wall (e.g. *G. aggregatum*), a unit wall (most *Scutellospora* species), or an expanding wall. The evanescent wall, by definition, must be an outside wall. Only one species (*A. rugosa*) has a persistent membranous outer wall, although this was misinterpreted by Morton (1986a) as a unit wall.

Flexible walls (membranous, coriaceous, amorphous) usually are inner walls (C and D in Fig. 12). *Scutellospora erythropa* is unusual in that spores of this fungus have two membranous walls positioned between a thick outer unit wall and a thick inner laminated wall (Koske and Walker, 1984). However, photographs in the protologue would suggest that this inner laminated wall could be a flexible coriaceous wall.

It is possible for all three flexible wall types to be found together as inner walls in *Acaulospora* and *Scutellospora* species (e.g. *S. pellucida*). To date, the amorphous inner wall of spores in *Acaulospora* is adherent to a "beaded" membranous wall and that in spores of *Scutellospora* is associated with a coriaceous wall (Morton, 1986a; Morton and Koske, 1988; Walker, pers. commun.).

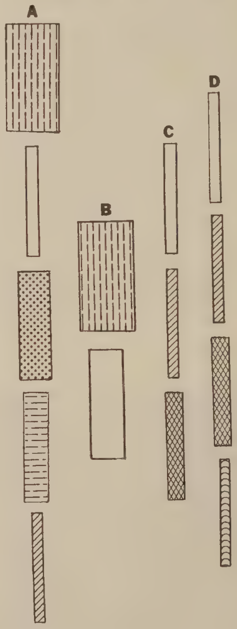

Fig. 12. Illustration of the relative positions of different wall types in spores of VA mycorrhizal fungi. Columns represent different wall groups: A = outer walls, B = structural walls, C = inner walls, D = innermost walls. Any combination of walls in a column can form a wall group.

ERRATA, VOLUME THIRTY-TWO

Page 284	line	45	for	*E.*	read	*Entrophospora*
303		35	for	*G.*	read	*Glomus*

Laminated or unit walls with ornamentations often are outer walls. This is especially true in *Scutellospora*. Exceptions are *A. appendicula* (unit walls 2 and 3 with colliculate projections and depressions, respectively), *A. gerdemannii* (wall 2 with alveolate reticulum), *G. halonatum* (laminated wall 2 with spines), and *G. monosporum* (laminated wall 2 with short spines).

Diversity in the number and types of walls present in a spore increases the difficulty in ascertaining wall structure, yet it also contributes to more accurate identification of species. In many of these taxa, difficulties in recognizing a particular wall type (e.g. a coriaceous versus a membranous wall) can be offset by combining other diagnostic characteristics of wall structure. One of the major difficulties in separating taxa in *Glomus* and *Gigaspora* is the absence of distinct differences in wall structure.

6. Reaction of walls to Melzer's reagent

Reaction of spore walls to cotton blue (Miller and Walker, 1986; Trappe, 1979; Schenck et al., 1986; Walker, 1982) and ammonical Congo red (McGee, 1986; Tandy, 1975) have been reported for only a limited number of the VA mycorrhizal fungi. Because these stains have been used infrequently, they currently have little taxonomic value.

Melzer's reagent appears to offer the greatest potential to aid in identifying VA mycorrhizal fungi. This reagent, consisting of 0.5 g iodine, 1.5 g potassium iodide, 20 ml chloral hydrate, and 20 ml water, was developed originally by Melzer (1924) to detect ornamentations on spores of *Russula* species.

A positive reaction in Melzer's reagent results in a color change in specific fungal structures. A blue, or amyloid, reaction has been used to separate Ascomycete (Kimbrough and Korf, 1967) and Basidiomycete (Lincoff, 1981; Singer, 1975) fungi. It has been termed "amyloid" because of similarities to the starch reaction. In Basidiomycete fungi, the amyloid reaction has been attributed to the binding of iodine with straight-chained a-1,4 glucosidic-linked polysaccharides (McCracken and Dodd, 1971). A red, or dextrinoid, reaction reported in fruit bodies of several Basidiomycete fungi may be due to high concentrations of the quaternary ammonium compounds (QACs) rather than amylose or amylopectin (Blackwell et al., 1985). These QACs form a red periodide complex with potassium iodide.

The true amyloid reaction has not been observed in walls of spores of VA mycorrhizal fungi. The dextrinoid reaction has been reported for the innermost membranous wall in spores of *G. fasciculatum*, *A. scrobiculata*, *S. calospora*, and *S. weresubiae* and the outer wall of *A. appendicula*. An orange reaction has been reported for the hyaline laminated wall of *G. albidum* and *S. fulgida* that could be considered dextrinoid if it has a reddish tinge. All other reactions grade between blue and red (e.g. light purple, red-purple, purple), a range not uncommon in other fungi (Singer, 1975). These color gradations relate to the chemical composition of spore walls (e.g. amylose, amylopectin, QACs) and the degree of polymerization of these compounds. Amylose, for example, reacts with iodine to form a purple to red-purple color when the degree of polymerization is between 30 and 40 glucose units (Bailey and Whelan, 1961). A faint red, red, and blue reaction occurs with 12, 15, and 45 glucose units, respectively. An orange or orange-red reaction in walls already containing red pigments (e.g. *G. versiforme*) is of doubtful significance, since Melzer's reagent is orange-yellow.

In Basidiomycetes, the color reaction in Melzer's reagent differs with fruit body ontogeny (Nannfeldt, 1976) or environmental conditions (Dennis, 1978). Similar causes of variation undoubtedly occur among VA mycorrhizal fungi. Reaction of an evanescent wall wall, for example, would be seen only on young spores before sloughing occurs. Variability in the staining reaction of the laminated wall has been reported for spores of *A. sporocarpia*, *S. pellucida*, *S. verrucosa*, and *S. weresubiae* (Berch, 1985; Koske and Walker, 1986). However, spores of *Scutellospora* species were collected from field soils where age and degree of wall modifications by hyperparasitic activity may have varied markedly among individuals. Spores of *A. sporocarpia* were described from herbarium rather than fresh specimens, and the type of preservation regime can reduce or completely inhibit Melzer's reaction (see Section IVE).

The color reaction of inner spore walls appears to be less variable under different environmental conditions. The dark red-purple reaction of the amorphous wall in spores of *A. dilatata*, *A. lacunosa*, *A. morrowae*, *A. rugosa*, *S. pellucida*, and *E. colombiana* has been consistent in field and pot culture soils and on different hosts (Morton, unpubl.). Innate chemical composition of the amorphous wall undoubtedly accounts for this distinctive chemical reaction with iodine (Morton, 1986b). The innermost membranous wall in spores of *A. longula*, *A. mellea*, and *A. rehmii* stain a light purple in Melzer's reagent (Schenck et al., 1984; Sieverding and Toro, 1987). Differences in polymerization of wall components may account for this less intense color reaction. The inner membranous wall of *A. foveata* and *A. tuberculata* stains orange-brown in Melzer's reagent (Trappe and Janos, 1982). The absence of photographic evidence makes it difficult to ascertain if this is a chemical reaction or perceived coloration from viewing the inner wall through the yellow-brown outer walls.

E. Factors modifying spore morphology

1. Chemical effects

The mountants most commonly used to preserve intact or broken spores on glass slides are listed in Table 1. Spores also can be mounted in water, but dessication quickly ensues and the internal contents of spores do not clear sufficiently to resolve the fine details of inner wall structure. Larger numbers of spores usually are preserved in lactophenol (also used as a mountant) or in 5% formalin or 5% gluteraldehyde. These compounds were not considered to have drastic effects on the spores (Schenck, 1982), but evidence now is accumulating to indicate otherwise. In fact, the effects of lactophenol are so great that this mixture should be avoided completely when mounting or storing spores.

a. Spore color. The walls of many spores of VA mycorrhizal fungi can darken measurably in phenol-based mountants or preservatives. Hyaline-spored species (e.g. *S. fulgida*, *G. occultum*, *G. diaphanum*) turn light yellow in PVL or darker yellow in lactophenol (Koske and Walker, 1986). Spores of *S. calospora*, which are normally hyaline to pale greenish-yellow, turn a darker olive-yellow. In all of these species, it is the spore walls which take on added pigments or color intensity. The cytoplasm of *Gigaspora gigantea*, which confers a bright yellow-green cast to spores in reflected light, will turn light to dark brown in almost any liquid over time. This color change is accelerated in phenol-based preservatives (Morton, unpubl.). Preservatives also can lighten spores by leaching pigments from spore walls. For example, pale to deep pink spores of *S. weresubiae* fade slowly in water or more rapidly in preservatives (Koske and Walker, 1986).

Table 1. Proportion of ingredients in compounds used to mount spores of VA mycorrhizal fungi on glass slides.

	% of solution (v/v)			
Solution[a]	Phenol	Glycerin	Lactic Acid	Polyvinyl-alcohol
Lactophenol	25	25	25	0
PVL	22	0	22	6
PVA	0	4	48	8

[a] PVL = Polyvinyl lactophenol, PVA = Polyvinyl lactic acid.

b. Spore wall structure. The effects of mountants and preservatives on spore wall structure have been documented by Morton (1986b). Phenol is a major culprit. It causes swelling of laminated walls, often obscuring laminae enough to give the appearance of one or more smooth unit walls. Membranous walls can swell to appear coriaceous, and the "beaded" ornamentations on inner membranous walls of *Acaulospora* species disappear. Phenol also interacts with spore wall components over time to retard or inhibit the dextrinoid or amyloid reaction in Melzer's reagent. The magnitude of these effects is proportional to the amount of phenol in the mixture.

Lactic acid affects spore wall structure and staining reactions by altering pH of the medium. Low pH elicits the "expanding" wall (*Glomus pansihalos*) and confers plasticity to the amorphous wall. Alone, lactic acid can retard iodine reactivity with spore walls, but this effect is reduced in solution mixtures.

Storage of spores in preservatives for extended periods of time (more than 90 days) can significantly transform spore wall structure. The most marked effects occur with the amorphous wall. While this wall is plastic in fresh specimens (Fig. 9G), it appears as a rigid unit wall of varying thickness, depending on the fungus, after preservation Fig. 9H). A similar transformation is evident for coriaceous walls in several undescribed *Scutellospora* species (Morton, unpubl.). The dark reddish-purple Melzer's reaction of the amorphous wall in fresh spores is replaced by a pale-brown to light pink reaction or no reaction after prolonged preservation. Melzer's reaction in spore walls also will fade on slides stored for extended periods of time if phenol is present in the mounting medium (Fig. 9G).

The same storage conditions also can reduce the apparent number of wall groups or the number of walls in each group. For example, the 6 walls of *S. pellucida* are reduced to only 2-3 discernible walls after storage for 90 days (Morton and Koske, 1988). Gibson (1985) reports only 2-3 walls in fixed spores of this fungus at the ultrastructural level. Such transformations are most serious in spores of most *Acaulospora* and *Scutellospora* species, since a number of flexible inner walls are present. Thin hyaline outer unit walls also are more difficult to detect after storage because of adherence to the next wall.

A positive effect of fixation is to improve resolution of the "beaded" membranous wall in *Acaulospora* (Fig. 9H) and render it impervious to the effects of phenol-based mountants.

2. Mechanical effects

The amount of pressure applied to break spores under a coverslip varies with viscosity of the mounting medium. Mountants such as glycerol, PVL, and PVA require greater pressure to break spores and "push" inner flexible walls into a position where they can be observed. Too much pressure invariable will cause significant disintegration or excessive "flattening" of thicker laminated or unit walls. These problems can be avoided by mounting spores under different coverslips to examine separately: (i) intact spores, (ii) spores broken lightly, (iii) spores with vigorous pressure applied, and (iv) spores crushed 2-3 times. The purpose of the last slide would be to make further attempts to separate thin inner flexible walls or to identify an amorphous inner wall.

F. Morphology of the sporogenous (subtending) hypha

1. Number of hyphae per spore

Taxa in most genera of VA mycorrhizal fungi form spores on or in a single hypha. The majority of taxa with multiple subtending hyphae are in *Glomus*. *Glomus glomerulatum G. halonatum*, *G. heterosporum*, and *G. lacteum* can form spores on 1-3 subtending hyphae, with the hyphal attachments usually near one end of the spores. *Glomus formosanum* and *G. multisubstensum* can have 1-4 sporogenous hyphae per spore. *Glomus multicaule* also has 1-4 hyphae, but the hyphae often are positioned at opposite ends of each spore. Two subtending hyphae of *G. glomerulatum* have been described at opposite ends of spores, but multiple hyphae are rare. Many taxa have been reported forming more than one subtending hyphae (e.g. *G. albidum*, *G. ambisporum*, *G. etunicatum*, *G. geosporum*, *G. maculosum*, *G. monosporum*, and *G. mosseae*), but this occurrence is infrequent and hence is of little taxonomic importance in these species. Similarly, two suspensor cells have been reported on spores of *S. heterogama*, but it is rare in pot culture populations (Morton, unpubl.).

2. Color of hyphae

The color of the sporogenous hyphae of most *Glomus*, *Sclerocystis*, *Gigaspora*, and *Scutellospora* species is reported or assumed to be concolorous with the spore wall. Exceptions are *G. invermaium* and *G. tenebrosum*. The subtending hypha of the former is colorless, yet the hyphal wall is continuous with the dark brown laminated wall of the spore. In the latter fungus, a similar break in wall color occurs at the juncture point of spore and hypha.

3. Shape of hyphae

The shape of the subtending hypha is highly variable in *Glomus* (Fig. 13). Most species have only a cylindrical hypha at the point of attachment (40%), or grade between a cylindrical and a flared hypha (21%). The subtending hypha also can range in shape from funnel-shaped (infundibuliform) to irregular to constricted. Funnel-shaped hyphae most commonly is associated with spores of *G. mosseae* and *G. monosporum*, where it is observed with high frequency. Even though a particular hypha shape may predominate in a spore population, it rarely is consistent on all spores. In two collections of *G. constrictum* in West Virginia, for example, fewer than 50% of the spores showed hyphal constrictions at the spore base (Morton; Walker, unpubl.). *Glomus aggregatum* exhibits the greatest gradation in hyphal shape, ranging from cylindrical to constricted. However, the mode of spore formation is highly variable (Koske, 1985). Spores of most species are borne on straight hyphae, but the subtending hypha of some species can curve sharply near the point of attachment. A comparison

306	30	for	*G. invermaium*	read	*Glomus invermaium*
482	30	for	*A.*	read	*Ascochyta*

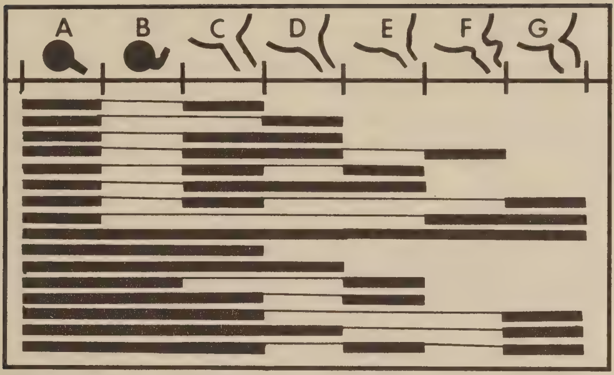

Fig. 13. The range in shape of the subtending hyphae of spores in *Glomus*. A = straight, B = recurved, C = cylindrical, D = flared, E = funnel-shaped, F = irregular, G = constricted. Thickened bars indicate shapes reported in species descriptions. Taxa with the same range in hypha (or suspensor) shape are pooled on the same line.

of taxa (Fig. 13) reveals that this characteristic is neither consistent nor diagnostic. However, variation in this trait among isolates must be examined to verify this conclusion.

The shape of the hypha subtending spores of *Sclerocystis* has been poorly documented, but illustrations and photographs suggest they most commonly are cylindrical or irregular.

Spores of *Acaulospora* and *Entrophospora* are borne consistently on or in, respectively, a tapering hypha attached to the sporiferous saccule. The dimensions of this hypha, rather than its shape, allows for some distinctions between species (see Section F5).

Spores of *Gigaspora* and *Scutellospora* are borne on inflated "bulbous suspensor cells" which are pyriform in shape. However, curvature of the sporogenous hypha can vary from straight to recurved. This characteristic cannot be weighted heavily, however, because it is not consistent on most spores in a population.

4. Number of hypha walls

In most taxa of VA mycorrhizal fungi, the sporogenous hypha has only one wall. At least 16 *Glomus* species have two or more walls extending some distance down the hypha from the attachment point. At least one of these walls is contiguous with a spore wall, but the details of wall structure at the juncture between spore and hypha have not been scrutinized. Hyphal wall structure appears to fall into three broad groups at this time:

The first group includes *G. albidum*, *G. etunicatum*, *G. intraradices*, *G. pansihalos*, and possibly *G. hoi* (based on illustrations in the description). All of these fungi have a subtending hypha with two walls, with the outer wall being evanescent and sloughing. The inner wall is contiguous between spore and subtending hypha. The inner hypha wall can be fragile and difficult to see with sloughing of the outer wall in several species (e.g. *G. albidum* and *G. etunicatum*).

The second group includes *G. caledonium*, *G. invermaium*, and *G. pustulatum*. These fungi also have a subtending hypha with two walls. As in the first group, the inner hypha wall is contiguous with the laminated spore wall, although this has been detailed only for *G. pustulatum*. The outer hyphal wall, which extends only a short distance from the spore, is not evanescent.

The third group includes *G. aggregatum*, *G. australe*, *G. clarum*, *G. dimorphicum* (both morphotypes), *G. halonatum*, *G. macrocarpum*, *G. microaggregatum*, and *G. segmentatum*. The subtending hypha of these fungi has two walls, with the outer wall continuous between spore and hypha. In all but *G. aggregatum* and *G. microaggregatum*, this outer wall is hyaline. The inner hypha wall is contiguous with the pigmented, laminated spore wall, and it extends only a short distance into the hypha.

The above-mentioned groupings are speculative at this time, because events in hyphal wall development, especially in relation to spore wall ontogeny, still are unknown. Stability of these characteristics under different physiological or ecological pressures also has not been evaulated. Characteristics of sporogenous hyphae might have considerable more weight in classification and identification with such information.

In stained preparations under the electron microscope, Gibson (1985) observed a thin outer wall on the suspensor cell of several *Gigaspora* and *Scutellospora* species which was contiguous with the thin hyaline outer wall of attached spores. This hyphal wall does not appear to be visible at the light microscope level.

5. Width of hyphae or suspensor cells

In this review, width of the subtending hypha is compared among taxa using a midpoint hypha width (mid-width) calculated from maximum and minimum values (Fig. 14). Variability in hyphal width is evaluated by comparing differences between maximum and minimum hypha widths (Fig. 15). Only in *Glomus* is the mid-width of the subtending hypha less than 5 µm (Fig. 14). Hypha mid-width grades between 6 and 15 µm for most taxa in *Glomus* (41 species). *Sclerocystis* also falls within these limits, but hypha width has been reported for only one fungus (*S. clavispora*). Hypha mid-width falls between 21 and 25 µm for 6 *Glomus* species. *Glomus clarum*, *G. magnicaule* and *G. botryoides* have the widest subtending hypha (mid-width of 48, 47, and 42 µm, respectively). Measurements of hypha width has not been reported for eight *Glomus* species. The subtending hypha varies in width from 1 to 5 µm, 6 to 10 µm, and 11 to 20 µm in 32%, 35%, and 18% of the taxa in *Glomus*, respectively (Fig. 15). The greatest range in hypha width is reported for *G. intraradices*, *G. magnicaule*, *G. tenebrosum* (about 25 µm) and *G. clarum* (65 µm).

The mid-width of the sporogenous hypha of most *Acaulospora* species falls between 6 and 20 µm at the point of spore attachment. Outside this range are *A. foveata*, *A. gerdemanni*, and *A. laevis*, with hypha mid-widths between 30 and 40 µm. The sporogenous hypha of *A. elegans* is the widest (50 µm). Measurements of hyphal width have not been reported for six *Acaulospora* species. Taxa in *Acaulospora* are divided almost equally into groups with the hypha varying in width from 1 to 5 µm, 6 to 10 µm, and 11 to 20 µm (Fig. 15). *Acaulospora foveata* exhibits the most variation, with 75 µm between minimum and maximum widths.

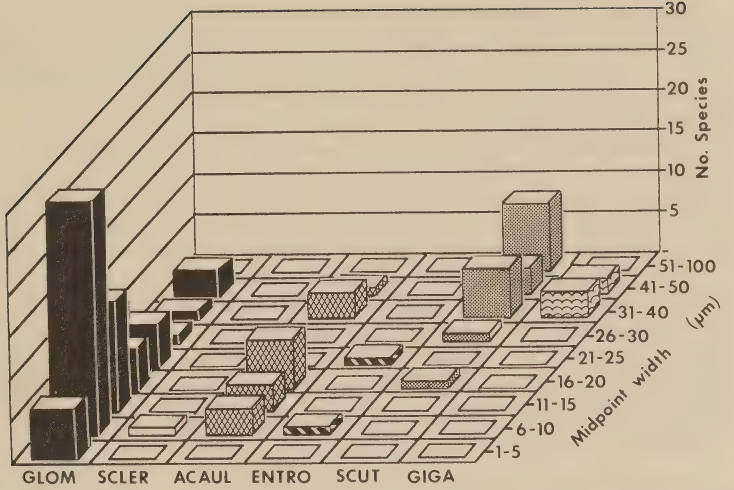

Fig. 14. Width of the sporogenous hypha (or suspensor cell) in taxa of all genera of VA mycorrhizal fungi, calculated as the midpoint between reported maximum and minimum values (Max. width - Min. width/2 + Min. width). GLOM = *Glomus*, SCLER = *Sclerocystis*, ACAUL = *Acaulospora*, ENTRO = *Entrophospora*, SCUT = *Scutellospora*, and GIGA = *Gigaspora*.

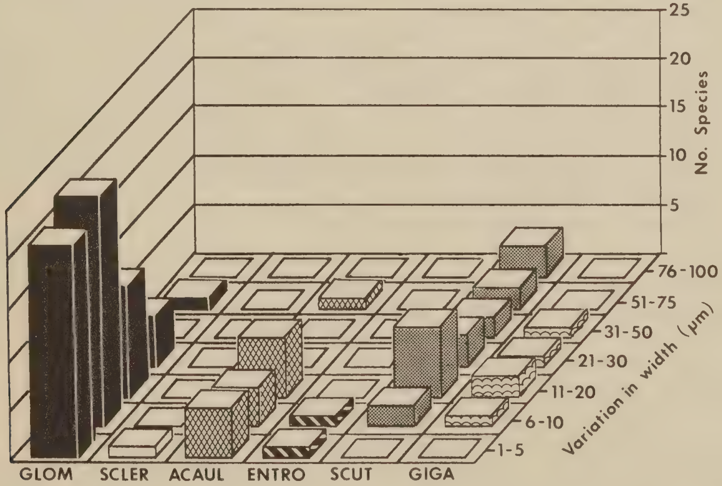

Fig. 15. Variation in width of the sporogenous hypha (or suspensor cell) in taxa of all genera of VA mycorrhizal fungi, calculated as the difference between reported maximum and minimum values (Max. width - Min. width). See **Fig. 14** for explanation of genus abbreviations.

In *Entrophospora*, hypha width at the end of the spore in proximity to the sporiferous saccule differs for each of two species (no data is available for *E. infrequens*). The hypha mid-width of *E. schenckii* is much narrower (9 µm) than that of *E. colombiana* (25 µm), but the enclosed spores also differ greatly in size (mid-diam of 61 and 105 µm, respectively).

Mid-width of the bulbous suspensor cell falls between 30 and 100 µm for most *Scutellospora* species, the exceptions being *S. pellucida* (20 µm) and *S. minuta* (27 µm). *Scutellospora reticulata* has the widest suspensor cell (93 µm). Variability in suspensor cell was small (10 µm) for only two species (*S. minuta* and *S. coralloidea*). Suspensor cell width varied between 11 and 20 µm for 37% of the taxa and between 21 and 95 µm for the remaining taxa. *Scutellospora erythropa* and *S. reticulata* have the greatest variability, with 95 µm between maximum and minimum values for both fungi.

None of the taxa in *Gigaspora* have a suspensor cell with a mid-width greater than 50 µm. All fall between 30 and 50 µm. Suspensor cell width has not been reported only for *G. decipiens*. Differences between maximum and minimum suspensor cell width do not exceed 35 µm in the descriptions to date.

6. Spore diameter:Hypha width ratios

Spore:hypha ratios may be useful in differentiating species because spore diameter and hypha width are not proportional for most VA mycorrhizal fungi. Very little can be said of *Sclerocystis* with hypha measurements being unreported for 8 of the 9 species. The same applies *to Entrophospora*, with only three species described to date.

A spore:hypha (or suspensor) ratio between 5 and 10 is most common for *Glomus*, *Acaulospora*, *Scutellospora*, and *Gigaspora* (50%, 80%, 63%, and 100% of taxa, respectively). Ratios less than 5 are found in only two *Glomus* species (*G. clarum* = 4.1 and *G. magnicaule* = 4.3), one *Acaulospora* (*A. elegans* = 4.5) and seven *Scutellospora* species (*S. reticulata* = 3.8, remainder = 4.4-4.8). Fourteen *Glomus* species and one *Scutellospora* (*S. tricalypta*) have ratios between 10 and 15. In *Glomus*, six species have ratios between 15 and 20, and another eight have ratios between 21 and 25. *Glomus scintillans* has the narrowest hypha in relation to spore mid-diam (ratio = 24.5). The only other genus with spore:hypha ratios greater than 15 is *Acaulospora* (*A. tuberculata* = 20 and *A. bireticulata* = 35).

7. Features of the pedicel in *Acaulospora*

Currently, four described *Acaulospora* species form spores on a pedicel branching from the hypha subtending a sporiferous saccule: *A. appendicula*, *A. nicolsonii*, *A. myriocarpa*, and *A. sporocarpia*. Of these, only the last two fungi form sporocarps. In field-collected material, the pedicel can remain attached to spores after saccules are detached. In these instances, the spores often can be mistaken for a *Glomus* species. Many spores must be examined to detect this feature and pot cultures should be established to follow spore ontogeny and confirm genus identity.

Characteristics of the pedicel region are not well described. The pedicel is firmly attached to spores of *A. appendicula*, probably because of the thick walls which prevent detachment from spores during extraction. The pedicel is found less frequently on spores of *A. myriocarpa* after extraction. The outer wall of spores of *A. appendicula*, *A. myriocarpa*, and *A. nicolsonii* is not continous with the wall linking pedicel and saccule hypha. This outer wall is separable on spores of *A. nicolsonii* and *A. appendicula*. It is evanescent in the former (Walker et al., 1984), but persistent in the latter (Morton, unpubl.). The outer spore wall appear to be continuous with the wall of the pedicel only in *A. sporocarpia*.

G. Occlusion of spores

Spore contents must be partitioned from the cytoplasm of the vegetative hypha to permit differentiation and maintain physiological integrity. The channel (pore) connecting spore and hypha of VA mycorrhizal fungi is occluded by a plug, a septum, wall thickening, or a flexible inner wall. All of the above-mentioned occluding mechanisms have been observed in *Glomus*, but with considerable inter- and intra-specific variation. The absence of any type of occluding mechanism has been reported for only three fungi: *G. invermaium*, *G. reticulatum*, and *G. tenebrosum*. It is unlikely that the pore always remains open in these taxa. Rather, this condition probably is common in young spores regardless of the eventual occluding mechanism. Gradual occlusion of an open pore by thickening of a laminated wall has been documented from pot cultures only for *G. fecundisporum* (Schenck and Smith, 1982), but the same events probably occur in spores of most other species. The process of wall thickening is assumed to involve the synthesis of additional laminae during spore development.

Some species (*G. albidum*, *G. arborense*, *G. multisubstensum*, *G. occultum*) have either an open pore or form a septum in spores of the same population. In other species (*G. australe*, *G. diaphanum*, *G. microaggregatum*) the pore appears to remain open or spore contents are partitioned off by an inner wall. In these fungi, it is uncertain if the variability is genetic or due to stage of spore development.

Confusion seems to pervade the literature as to what constitutes a septum. It is thin, often cup-shaped, and can form either at the juncture of spore and hypha (in 12 species) or some distance down the hypha (*G. caledonium*, *G. constrictum*, *G. cerebriforme*, *G. delhiense*, *G. halonatum*, *G. monosporum*, *G. mosseae*, *G. multisubstensum*). Morphogenesis of septa in these species has not been examined, making it difficult to make comparisons with non-VA mycorrhizal fungi (see Fig. 2). The septum can arise either from a lamina of the laminated wall or from the hyphal wall in spores of those species lacking a flexible inner wall (*G. boreale*, *G. canadense*, *G. delhiense*, *G. deserticola*, *G. fragile*, *G. fulvum*, *G. halonatum*, *G. heterosporum*, *G. monosporum*, *G. mosseae*, *G. multisubstensum*, *G. pulvinatum*). The "septum" may be a continuation of a membranous inner wall, when the latter is formed (e.g. *G. cerebriforme*, *G. hoi*). However, the protologues of these species do not shed light on origin of the membranous closure. Only in the description of *G. maculosum* is it mentioned that a septum develops from the laminated wall, despite the presence of an inner membranous wall (Miller and Walker, 1986).

Protologues of *G. diaphanum* (Morton and Walker, 1984), *G. geosporum* (Walker, 1982), and *G. microaggregatum* (Koske et al., 1986) mention that the inner flexible wall "forms a septum". Such wording suggests synonymy between a septum and a flexible inner wall, but each structure may have a different origin or function. The septum is a morphologically distinct structure, whereas the inner wall often forms an "endospore" enclosing the spore contents. Sieverding (1987) observes that spores of *G. glomerulatum* formed on septate hyphae are occluded by a septum whereas those formed on aseptate hyphae are occluded by a membranous inner wall. This observation begins to pinpoint sources of variation in occluding mechanisms.

Based on descriptions in protologues, five species (*G. etunicatum*, *G. glomerulatum*, *G. macrocarpum*, *G. manihotis*, *G. pallidum*) form spores occluded by either wall thickening or a septum. In *G. etunicatum*, a thin septum is present in young spores, but older spores are occluded by the laminated wall (Becker and Gerdemann, 1977). Variability within a single spore population generally is unknown, although septum formation in *G. macrocarpum* spores is reported as occurring only "rarely" (Berch and Fortin, 1983c).

Some *Glomus* species form a plug to partition off spore contents, but a flexible inner wall (*G. ambisporum*, *G. dimorphicum*) or thickening by a laminated wall (*G. globiferum*, *G. radiatum*) also can be observed. Only *G. aggregatum* spores are occluded by a wide range of mechanisms: a septum, inner wall, or inner wall thickening. However, spore formation also is quite variable within single sporocarps of this fungus (Koske, 1985). The extensive morphological and ontogenetic variability observed in sporocarps of *G. aggregatum* needs to be confirmed from living pot cultures.

Misinterpretations of occluding structures because of (i) spore age or (ii) problems in the identification cannot be reconciled easily at this time. Clarification will come only with reexamination of preserved and fresh material. Characteristics of spore closure could play as important a role as spore wall structure in identification and classification of *Glomus* species if structures are more clearly defined and their stability can be assessed under different ecological pressures.

The occluding mechanism in *Sclerocystis* spores is not well documented, perhaps because most species have been examined only from field-collected material. Nonetheless, descriptions indicate that the pore of *S. microcarpus* and *S. rubiformis* spores remains open and that a septum closes off the spore contents in spores of *S. coremioides*, *S. dussii*, and *S. pachycaulis*. Occlusion in the other four species remains unknown.

In *Acaulospora*, the pore between spore and hypha appears to be occluded by wall thickening. This is surmised by the lack of any discontinuity between the spore wall and the wall material in the occlusion. The site of attachment between spore and hypha usually can be detected by an external thickened scar which is the fracture line. Occlusion in *Entrophospora* appears to be similar to that of *Acaulospora*. Fracture scars can be seen at opposing ends of spores of these taxa. Unfortunately, no light or electron microscopic studies have been undertaken to document stages of occlusion in developing spores of taxa in either genus. Also, no histochemical tests been performed to verify the absence of differences in wall composition at the attachment site.

Thickening of the laminated wall is the only reported mode of occlusion in spores of *Gigaspora* and *Scutellospora* species. However, this has been described only for two and nine taxa in each genus, respectively. Most evidence indicates that the mechanism of occlusion is unlike that of *Acaulospora* and *Entrophospora*, where a spore forms as a discrete entity from any hyphal attachment. Most descriptions suggest that the pore between spore and suspensor cell is occluded or partially open and that the laminated spore wall may be continuous with the suspensor cell wall. It is unclear how much the process of occlusion in taxa of these two genera differ from that in *Glomus* or *Sclerocystis*.

H. Morphology of the sporiferous saccule

1. Color of saccule

The color of the sporiferous saccule formed by *Acaulospora* and *Entrophospora* species is not taxonomically distinctive. Saccules of all taxa are reported as being white when cytoplasm is present. In several species (*A. appendicula*, *A. dilatata*, *A. lacunosa*, *A. rugosa*), the contents of the saccule may grade into a greyish-white to cream to pale yellow color. The saccule of *A. spinosa* and *A. tuberculata* appears yellow and that of *A. elegans* a pale brown, but this pigmentation is due to color of the saccule wall and not the cytoplasmic contents.

2. Shape of saccule

The sporiferous saccule of most taxa is globose to subglobose. However, it also may be ellipsoid (*A. gerdemannii*, *E. infrequens*), ovoid (*A. myriocarpa*), obovoid (*A. trappei*, *E. infrequens*), or irregular (*A. sporocarpia*). Saccule shape is not sufficiently different among taxa to have much significance in identification.

3. Diameter of saccule

Diameter (mid-diam, as with spores) of the sporiferous saccule mirrors spore size in most taxa. In fact, protologues of *A. laevis* and *A. spinosa* indicate the saccule is the same size as the spore. As usual, however, there are several exceptions to this generalization. The saccule of *A. gerdemannii* grades from 290 to 365 µm in diameter, but spores do not exceed 250 µm. Similarly the saccule of *A. sporocarpia* varies between 210 and 275 µm mid-diam, whereas the spores are smaller than 200 µm.

4. Walls of saccule

Based on only a few accounts, the sporiferous saccule of most taxa consists of a "thin" (0.5-1 µm) hyaline wall continuous with the subtending hypha. Wall thickness may be variable, as noted in different isolates of *A. foveata* (Schenck et al., 1984; Janos and Trappe, 1982). Only in the case of *E. infrequens* does the saccule wall appear to be consistently thick (2.5-10 µm), and this wall also envelopes the spore. The wall structure of the sporiferous saccule is most complex for *A. appendicula* and *A. nicolsonii*. The saccule of the former fungus consists of an outer wall with overlapping plate-like structures and an inner membranous wall. The saccule of *A. nicolsonii* has an evanescent, granular outer wall and an inner unit wall. It is unclear how wall structure of the saccule relates ontogenetically to spore development.

I. Interhyphal distance between spore and saccule

The intercalary hyphal distance between sporiferous saccule and spore has been documented only for ten *Acaulospora* species. This distance varies between 50 and 100 µm for *A. dilatata*, *A. foveata*, *A. lacunosa*, *A. denticulata*, and *A. rehmi*. In several other species (*A. morrowae*, *A. rugosa*, *E. colombiana*), this distance may extend an additional 25-60 µm. In two species (*A. longula* and *A. nicolsonii*), it ranges between 100 and 200 µm.

J. Non-morphological characteristics

1. Biochemical characteristics

Biochemical criteria to separate VA mycorrhizal fungi have been limited so far to defining stained isozyme banding patterns from spores (Sen and Hepper, 1986; Hepper et al., 1988) and mycorrhizal infection (Hepper et al., 1986) after polyacrylamide gel electrophoresis. The most common enzymes assayed were esterase, glutamate oxaloacetate transaminase, hexokinase, malate dehydrogenase, peptidase, and phospho-glucomutase. Based on results using spores of five *Glomus* species, malate dehydrogenase was most diagnostic for distinguishing between pairs of fungi (Sen and Hepper, 1986). However, the differences were not clear cut when mobility and intensity of staining were examined together. Mobility of six enzymes was similar for *G. caledonium* propagated under differing host-soil conditions, although intensity of staining was highly variable. A comparison of isolates of different species revealed that similar banding patterns were clustered into three groups of fungi: (i) *G. caledonium*, (ii) *G. clarum* and *G. manihotis* isolates, and (iii) *G. mosseae* and *G. monosporum* isolates (Hepper et al., 1988). Unfortunately, morphological features of each isolate were not documented.

A major weakness of this work is that isolate versus species differences were not verified on morphological grounds. No voucher specimens were saved so that other scientists could examine experimental material. Results of such studies can be of great taxonomic significance, but only if they are linked to current morphological criteria. To have validity, biochemical results must be connected in some way to the nomenclatural type of a species. Ongoing studies, fortunately, appear to be moving toward establishing such a connection (Rosendahl and Hepper, 1987).

2. Immunological characteristics

Two approaches have been used thus far to identify specific VA mycorrhizal fungi: the fluorescent antibody (FA) technique and the enzyme-linked immunosorbent assay (ELISA). In these assays, specificity is conferred by the antibody. Serum antibodies against intact hyphae with the FA method (Kough et al., 1983; Wilson et al., 1983) or homogenized hyphae with ELISA (Aldwell et al., 1983) reacted not only with the target fungi, but also with other species in the same genus. Cross-reactivity was less evident when target fungi were in different genera (Aldwell and Hall, 1986; Aldwell et al., 1983).

Monoclonal antibodies (MAbs), each of which is secreted by an immortal hybridoma culture derived from a single B-lymphocyte, are much more specific and therefore overcome problems associated with interspecific cross-reactions. Wright et al. (1987) demonstrated that MAbs against spores and hyphae of the target fungus, *G. occultum,* but did not react against 15 other *Glomus* species or 14 VA mycorrhizal fungi in other genera. MAbs reacted against 15 isolates of *G. occultum* (based on equivalence in spore morphology and mycorrhizal infection characteristics), but the intensity of the reaction differed significantly. These data suggest that MAbs may differentiate strains of a fungus, but proof will come only by comparing single-spore isolates. Even though these workers have maintained living cultures of all isolates tested, they too have been guilty of not depositing voucher specimens to permit verification of species or isolate integrity on morphological grounds. This is being rectified, particularly as single spore isolates are developed for testing (Morton, unpubl.).

3. Genetic characteristics

Analysis of relatedness or difference in rRNA nucleotide sequences has been useful in examining phylogenetic relationships among ascomyceteous (Chen et al., 1984) and basidiomyceteous (Huysmans et al., 1983) fungi. Assessment of DNA homology by hybridization has been used to separate bacterial species (Johnson, 1973) and more recently basidomyceteous fungi (Jahnke and Bahnweg, 1986). The study of VA mycorrhizal fungi at the molecular level has considerable value in both classification and identification, since it provides the opportunity to assess true phylogenetic affinities between species. It must be emphasized again that such an approach will have little impact, however, if results cannot be linked or correlated with morphological characteristics of the fungi under study.

DNA has been extracted from *Endogone pisiformis* (Millner, 1987), but yields were very low (0.13%). A limiting factor in these types of studies, for the present, will be the amount of fungal material available for extraction of DNA. Not only will it be necessary to maximize productivity of pot or tissue cultures of target fungi, but these cultures also will need to be started from single spores to establish potentially homogeneous germplasm.

V. CONCLUDING REMARKS

Classification and identification of VA mycorrhizal fungi remains in the formative stages of growth, with all the attendant turmoil. Still, much now is being learned about the extent of species diversity occurring in nature. This information can provide important clues of phylogenetic relationships among taxa in view of the paucity of information in the fossil record.

Although the classification system erected by Gerdemann and Trappe in 1974 has accommodated changes so far, it continues to be plagued by vague generalizations, inconsistent species descriptions, restricted accessibility to type material, and too much "a priori" weighting of some morphological characters at the expense of others. As much, if not more, emphasis now needs to be placed on overcoming these problems as on finding new species. Greater efforts must be made to incorporate quantitative data to permit evaluation of intra- and inter-specific variability so that the stability of taxonomic characteristics may be judged under different physiological and ecological pressures. Ontogeny of spore development must receive closer attention, and this will require a synthesis of pot culture techniques to facilitate broader application. Genetic, biochemical, and immunological information has the potential of providing valuable data on relationships among taxa at the molecular level and of also improving methods for rapid and accurate identification of species or strains. Trappe (1988) points out the need for "mutualism" between the taxonomist and scientists in other allied disciplines such as ecology, biochemistry, molecular biology, and statistics to maintain vitality in the science of taxonomy and the study of VA mycorrhizal fungi.

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A NEW SPECIES OF HETEROBASIDION (POLYPORACEAE) FROM AUSTRALASIA

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SUMMARY

Heterobasidion araucariae sp. nov., previously considered to be a form of *H. annosum* (Fr.) Bref., is distinguished by larger pores, basidiospores and conidia, by homothallic sexuality, by a restricted host range and distribution, and by a reduced level of pathogenicity. A key to the three accepted species of *Heterobasidion* is provided.

Heterobasidion Bref. is a well defined polypore genus characterised by pilei with a distinct cuticle, dextrinoid skeletal hyphae, asperulate basidiospores, and a *Spiniger* Stalpers anamorph. The genus has been considered as containing only 2 species, the saprophytic *H. insulare* (Murr.) Ryv. confined to Asia, and the widespread, economically important root pathogen of conifers, *H. annosum* (Fr.) Bref. *H. annosum* was first described from *Betula* (Fries, 1821), and is reported from most temperate regions of the northern hemisphere as well as parts of Australasia (Anon., 1980). Comparison of the fungus described as *H. annosum* from the two hemispheres reveals differences in fruitbody morphology, sexuality, pathogenicity, and host range, and justifies the description of the Australasian fungus as a new species.

HETEROBASIDION ARAUCARIAE sp. nov. (Fig. 1-3)

Fructificatio annua, interdum perennis, resupinata, effuso-reflexa vel pileata. Pileus late affixus, variabilis, applanatus, ungulatus vel convexus, 3.5–19 cm latus, 2.5–17 cm radius, 1.5–8 cm basi crassus, superficie glabra, concentricaliter sulcata, brunnea, interdum ad marginem cremea. Pori facies cremea; pori 1–2(–3) per mm, angulati ad subdaedalei. Contextus cremeus, ad 2 cm crassus; cutis fusca, ad 170 µm crassa. Systema hypharum dimiticum; hyphae generatoriae effibulatae, hyalinae; hyphae skeletales dextrinoideae. Sporae hyalinae, ovatae, nondextrinoideae, (4.7–)5.7(–8.3) x (3.7–)4.6(-6.0) µm, muris echinulatis.

Holotypus: New Zealand, Northland, Waipoua Forest Sanctuary, Yakas Kauri Track, on fallen branch of *Agathis australis*, leg. P.K. Buchanan no. 85/299, 25 Sep 1985 (PDD 48002).

Etymology: *araucariae*, from host genus *Araucaria* (Araucariaceae).

BASIDIOCARPS annual, occasionally perennial, resupinate, effused-reflexed, or pileate; when pileate broadly attached, variable in shape, applanate, ungulate or convex, often irregular, usually solitary; compressible to exude water droplets when fresh, corky hard when dry,; pilei 3.5–19 cm across, 2.5–17 cm radius, 1.5–8 cm thick at base; when effused-reflexed and extending along substrate branch, up to 62 cm long with numerous reflexed portions; when resupinate up to 50 x 36 cm.

PILEUS SURFACE glabrous, concentrically sulcate in narrow to broad bands, brown to red-brown or dark brown, sometimes concentrically zonate with narrow bands of different shades of brown; at margin on actively growing pilei cream-coloured in a narrow to broad band; margin rounded or sharp.

PORE SURFACE cream to light yellow-brown; pores angular to subdaedaleoid and sometimes radially elongated, 1–2(–3) per mm; tube mouths even; tubes up to 3.8 cm deep, concolourous with pore surface; in perennial fruitbodies, tubes weakly stratose and successive tube layers often receding; sterile margin 1–3 mm across.

CONTEXT cream, corky, azonate, mostly less than 1 cm thick, up to 2 cm thick at base, of intertwined hyphae; cuticle dark brown, shiny when cut, to 170 μm thick, composed of brown hyphae.

HYPHAL SYSTEM dimitic; generative hyphae thin-walled, simple septate, hyaline, nondextrinoid, 2.5–5.5 μm wide; skeletal hyphae dominating, straight to flexuous, sparingly branched, hyaline except in cuticle, dextrinoid, 2.5–6.5(–8) μm wide, with thickened walls to 2.8 μm thick.

BASIDIA 4-sterigmate, cylindrical to clavate or sometimes slightly constricted about the middle; c. 15–18 x 6–7 μm.

CYSTIDIOLES thin-walled, elongate, cylindrical, 3–6.5 μm diam., with one (rarely two) small apical bulbs; contents often granular; sometimes projecting beyond the hymenium.

BASIDIOSPORES ovate, often uniguttulate; wall minutely echinulate, hyaline in tubes, sometimes pale yellow-brown on pileus surface, up to 0.5 μm thick, IKI –; (4.7–)5.7(–8.3) x (3.7–)4.6(–6.0) μm; spore print white.

TYPE OF ROT: white.

CULTURAL CHARACTERISTICS:

COLONY on malt agar, usually white, sometimes pale yellow, translucent. Marginal hyphae appressed, widely spaced. Aerial mycelium appearing farinaceous to subfelty, consisting of erect, simple or branched conidiophores. Colony reverse white or pale yellow. Optimum temperature for growth: 23–25 C. Tests for extracellular polyphenol oxidases, using gum guaiacum solution, tannic acid agar, and gallic acid agar (Nobles, 1965), positive.

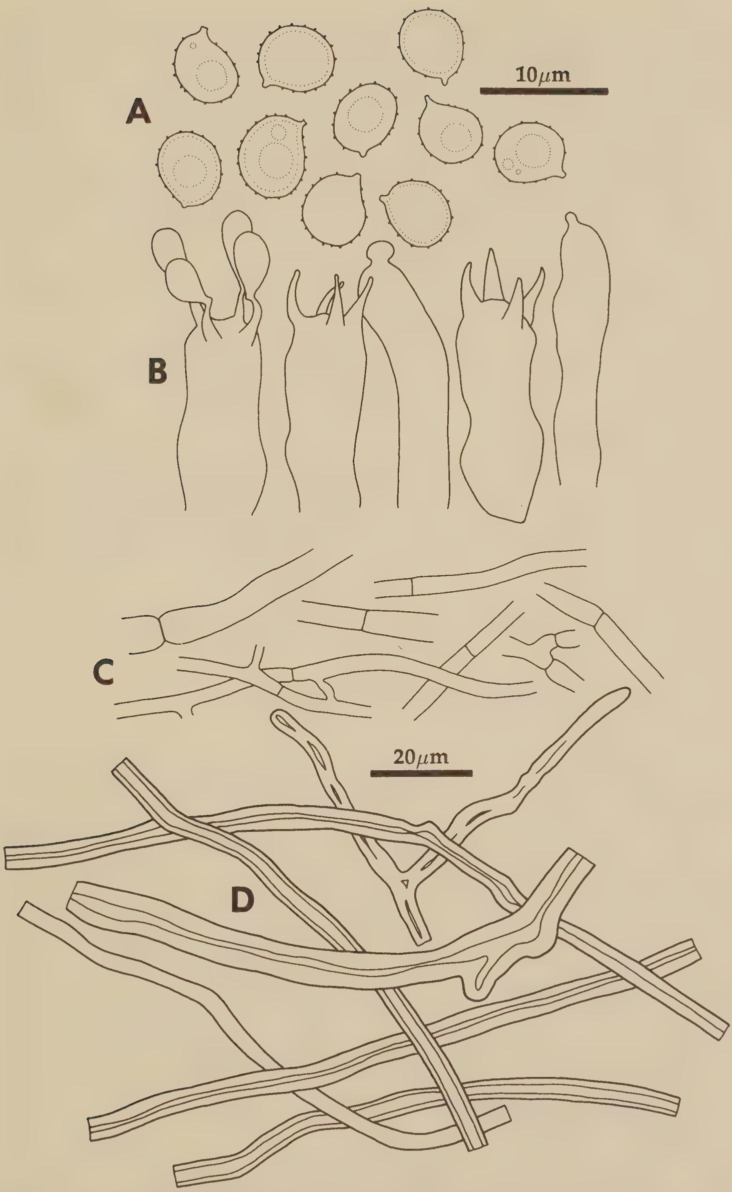


Fig. 1. *Heterobasidion araucariae*: A, basidiospores; B, basidia and cystidioles; C, generative hyphae; D, skeletal hyphae. (PDD 48002, holotype).

HYPHAE hyaline, thin-walled, up to 9 μm diam., simple septate or clamped, clamps present on wide, straight hyphae especially near margin; sulpho-positive hyphal elements present, thin-walled with short papillate side branches, cytoplasm granular or composed of tiny oil droplets; occasionally thick-walled, brown, interlocking hyphae forming crust in older parts of colony.

CONIDIOPHORES arising as erect branches from prostrate hyphae, often constricted at junction with hyphae, sometimes covered with granular material at base, simple or branched, variable in length, up to 400 μm long, 5.5–13.5 μm diam., with an apical, inflated conidiogenous vesicle, 7–19.5 μm diam., from which develops conidia on conical denticles.

CONIDIA subglobose, obovoid, or pyriform, unicellular, hyaline, smooth-walled, (5–)7.6(–16) x (3–)5.3(–13.5) μm; wall up to 0.5 μm thick.

SPECIES CODE (Nobles, 1965): 2,5,(6),7,(10),(11),(15), 33,36,(37),38,42,50,(53), 55,57.

SEXUALITY: homothallic.

HOSTS: recorded on Araucariaceae (*Agathis australis* (D. Don) Lindley, *A. vitiensis* (Seem.) Benth. & Hook. f. ex Drake, *Araucaria bidwillii* Hook., *A. cunninghamii* Aiton ex Don) and Pinaceae (*Pinus kesiya* Royle ex Gordon, *P. patula* Schlecht. & Cham., *P. taeda* L.); on stumps or dead standing and fallen wood, rarely on living wood.

DISTRIBUTION: Australia (eastern Queensland, northeastern New South Wales), New Zealand (northern North Island), Papua New Guinea, Fiji.

REPRESENTATIVE SPECIMENS EXAMINED:

(Herbarium abbreviations after Holmgren et al., 1981).

Heterobasidion araucariae:

-on *Agathis australis*: NEW ZEALAND, Northland, Omahuta Forest Sanctuary, 11 Sep 1984, P.K. Buchanan 84/250 (PDD 48003); Northland, Puketi State Forest, 12 Sep 1984, P.K. Buchanan 84/254 (PDD 48004); Northland, Trounson Kauri Park, 10 Sep 1984, P.K. Buchanan 84/241 (PDD 48005); Trounson Kauri Park, 14 Sep 1984, P.K. Buchanan 84/263 (PDD 48007); Trounson Kauri Park, 25 Sep 1985, P.K. Buchanan 85/300 (PDD 48013); Northland, Waipoua Forest Sanctuary, 1940, G.B. Rawlings (PDD 4126); Waipoua Forest Sanctuary, Yakas Kauri Track, 25 Sep 1985, P.K. Buchanan 85/299 (PDD 48002, holotype); Auckland, Waitakere Ranges, Cascade Kauri Park, Sep 1948, J.M. Dingley (PDD 6458); Coromandel, Little Barrier Is., Mt. Ohakiri, 12 Jun 1984, R.E. Beever, E.P. Laracy, P.K. Buchanan 84/135 (PDD 48006); Coromandel, Coromandel State Forest Park, Manaia Forest Sanctuary, 20 Mar 1985, I.A. Hood (PDD 49003 = NZFRI 3049M).

-on *Agathis vitiensis*: FIJI, Viti Levu, Nadarivatu Nature Reserve, 18 Apr 1985, T.G. Raravula (PDD 48008).

-on *Araucaria cunninghamii*: AUSTRALIA, Queensland, Benarkin, Sandy Logging Area, 31 Jul 1984, J. Tierney; Benarkin, Wallaby Logging Area, 31 Jul 1984, J. Tierney; Queensland, Imbil, *Araucaria* Logging Area, 1 Aug 1984, J. Tierney; Imbil, Branch Logging Area, 1 Aug 1984, J. Tierney; Queensland, Yarraman,

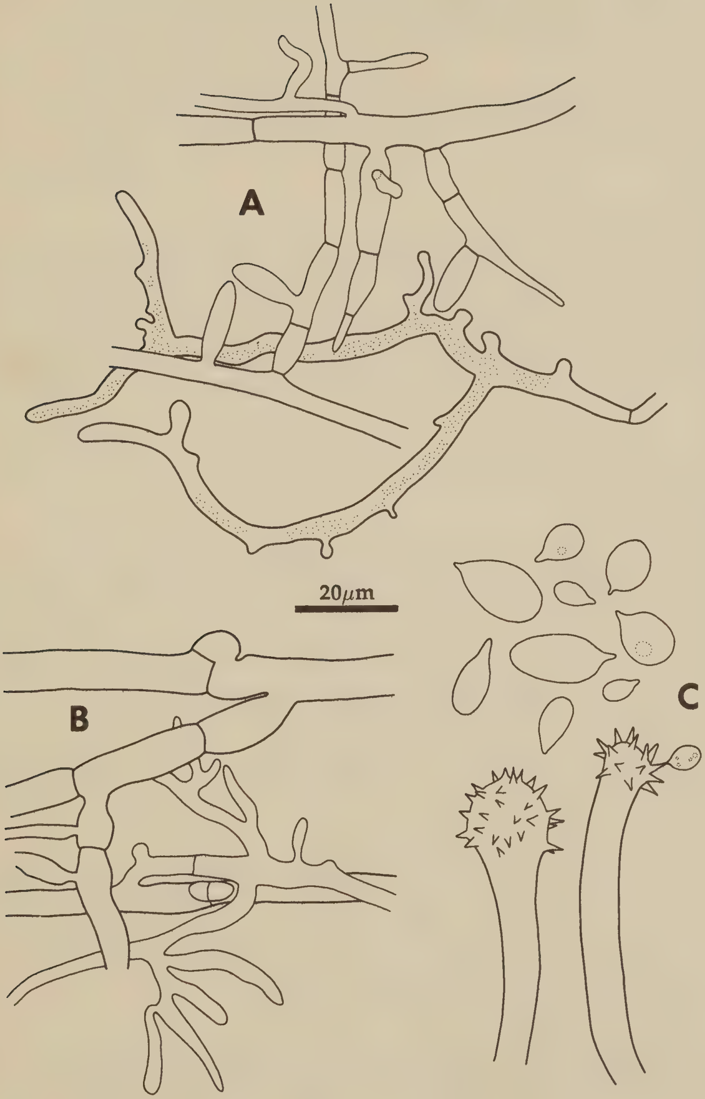


Fig. 2. *Heterobasidion araucariae*, cultural characters: A, simple septate hyphae and sulphopositive hyphae; B, clamped hyphae from colony margin; C, conidiophores and conidia. (ICMP 9533, ex holotype).

Cooyar Logging Area, 31 Jul 1984, J. Tierney. PAPUA NEW GUINEA, Woitape, 9 Nov 1977, J.A. Simpson (PDD 48009).

-on *Pinus kesiya*: PAPUA NEW GUINEA, Lapegu Cmpt. 1, 12 Apr 1978, J.A. Simpson (PDD 48011).

-on *Pinus patula*: PAPUA NEW GUINEA, Lapegu Cmpt. 6, 11 Apr 1978, J.A. Simpson (PDD 48010).

-on *Pinus taeda*: NEW ZEALAND, Northland, Waipoua Forest Sanctuary (NZFRI 1150M).

Heterobasidion annosum:

UNITED KINGDOM, England, Cambridge, Brackland, on *Pinus nigra*, Aug 1948, G.H. Cunningham (PDD 6383); England, Hertfordshire, Ashridge, on conifer, Nov 1951, D.A. Reid (PDD 1218); Scotland, Perthshire, vic. Dunkeld, The Hermitage, on *Picea* sp., 26 Sep 1983, N. Hallenberg (GB 931). ?INDIA, on *Picea smithiana*, 10 Sep 1941 (DD 3347). CANADA, British Columbia, Vancouver, Stanley Park, on conifer, 2 May 1939, W.D. Touzeau (PDD 28209 = DAOM 10764); British Columbia, Vancouver Is., Mesachie Lake, on *Tsuga heterophylla*, 12 Nov 1985, D. Morrison, P.K. Buchanan (PDD 48012). U.S.A., Virginia, Norfolk County, Great Dismal Swamp, on *Pinus taeda*, 11 Jan 1953, A.S. Rhoads (CFMR FP-103826).

Heterobasidion insulare:

INDIA, on *Abies pindrow*, 3 Oct 1966 (DD 7908); Matra, Feb 1934, Bagchee (O, ex K). NEPAL, Ringmo, on *Abies webbiana*, 9 Oct 1962, J. Poelt (O); prov. Ghorapani, Gandaki, on *Abies* sp., L. Ryvarden 18706 (O). BURMA, Victoria Reg., Southern Chin Hills, Estrakan, Nov 1956, F. Kingdon-Ward (O). JAPAN, Hokkaido, Furano-shi, Mt. Dairoku-san, Tokyo Univ. Forest in Hokkaido, on *Picea jezoensis*, 31 Aug 1982, S. T-Kunieda (O); Hokkaido, Furano, Yamabe, on *Pinus nigra*, 26 Sep 1962, Y. Hayashi (TFM-F-11828); Mie Pref., Ichishi, Misugi, 27 Aug 1967, H. Furukawa (TFM-F-11825); Chiba Pref., Kiyosumi, 23 Apr 1964, K. Aoshima (TFM-F-11827); Tokyo, Hachioji, Asakawa, 17 Oct 1963, Y. Hayashi (TFM-F-10177); Nagano Pref., Chiisagata, Wada, 6 Aug 1964, K. Aoshima (TFM-F-11826).

REPRESENTATIVE CULTURES EXAMINED:

(Abbreviations: DFP = Division of Chemical and Wood Technology, CSIRO, Highett, Victoria, Australia. ICMP = International Collection of Microorganisms from Plants (formerly PDDCC), Plant Diseases Division, DSIR, Auckland, New Zealand. LY = Université Claude Bernard-Lyon, Villeurbanne, France. NZFS = Forest Research Institute, Rotorua, New Zealand).

Heterobasidion araucariae:

-on *Agathis australis*: NEW ZEALAND, (for collection data, see above), ICMP 9529 ex PDD 48007; ICMP 9530 ex PDD 48003; ICMP 9531 ex PDD 48004; ICMP 9532 ex PDD 48005; ICMP 9533 ex PDD 48002 (holotype); ICMP 9534 ex PDD 48006.

-on *Agathis vitiensis*: FIJI, 1941 (ICMP 9535 = NZFS 24).

-on *Pinus taeda*: NEW ZEALAND, Auckland (ICMP 9536 = DFP 10220); J.W. Gilmour (ICMP 9537, from F.F. Lombard = NZFS 167d).

-on *Araucaria cunninghamii*: AUSTRALIA, Queensland, Imbil, 1 Apr 1970, B.N. Brown (ICMP 9538); Imbil, State Forest 135, Cmpt 11 *Araucaria*, 14 Jan 1985, J. Tierney 5549A (ICMP 9539).

-on *Araucaria bidwillii*: AUSTRALIA, Queensland, Imbil, 18 Aug 1976, L. Bolland (ICMP 9540).

Heterobasidion annosum:

UNITED KINGDOM (ICMP 9541 ex GB 931). FRANCE, Dordogne, Liorac-sur-Louyre, on *Pinus maritima*, Oct 1972, A. David (ICMP 9542 = LY-AD 3055). FINLAND, Ruotsinpyhtää, on *Picea abies*, 2 Nov 1983, K. Korhonen, S-group (ICMP 9543); Ruotsinpyhtää, on *Pinus sylvestris*, 2 Nov 1983, K. Korhonen, P-group (ICMP 9544). AFGHANISTAN, Kaboul, 1976, Lalande (ICMP 9545 = LY-AD 2031). CANADA, British Columbia, on *Tsuga heterophylla*, 24 Jul 1939, J.E. Bier (ICMP 9547 = DAOM F9326). U.S.A., California (ICMP 9546 = DFP 10257).

Heterobasidion annosum sens. lat. is considered to be heterogeneous. Differences in a combination of characters separate *H. araucariae* from *H. annosum sens. str.* Some of these differences have been previously noted by other authors but in isolation they were considered insufficient to delimit a separate species.

The fruitbody of *H. araucariae* is most readily distinguished macroscopically from *H. annosum* by pore size with significantly larger pores in *H. araucariae*; mean number of pores per mm for 45 dried fruitbodies from Australasia ranged from 1.7–2.7, while for 80 dried fruitbodies of *H. annosum* from the northern hemisphere pore size was 2.8–5.9 pores/mm (Hood, 1985). In addition to larger pores, Cunningham (1965) noted the apparent absence of strata in tubes of most Australasian specimens, but reported receding tube layers in old perennial specimens. Most collections of *H. araucariae* examined in the present study appeared to be annual, with tubes up to 25 mm in length. In perennial fruitbodies, tube length varied from 5 to 15 mm between strata, with successive tube layers often receding. In collections of *H. annosum* examined, tube length between strata was shorter, 2–6 mm. Ryvarden (1976) reported up to 4 mm between strata for *H. annosum*. Fruitbodies of *H. araucariae* were often larger than those typical of *H. annosum*, but both species display a wide range of fruitbody size and shape.

Microscopically, *H. araucariae* can be distinguished from *H. annosum* by larger basidiospores. Mean dimensions for basidiospores of *H. araucariae* (344 spores measured from 20 collections) were 5.74 x 4.62 μm, and for basidiospores of *H. annosum* (80 spores measured from 5 collections), 4.65 x 3.85 μm. The difference is statistically significant ($p < 0.001$) for both mean length (SED = 0.06) and mean width (SED = 0.05). The range of spore size for the two species overlaps somewhat: *H. araucariae* 4.7–8.3 x 3.7–6.0 μm, *H. annosum* 4.0-6.0 x 3.2-4.5 μm. Spores of both species are of similar shape, have an echinulate wall and are binucleate (Chase et al., 1985).

In culture, *H. araucariae* can be distinguished from *H. annosum* by larger conidia (Fig. 3,4). Fifty conidia were measured from each of 3 strains of *H. araucariae* (Australia, New Zealand) and from 3 strains of *H. annosum* (France, Afghanistan, U.S.A.). Conidia were sampled from 6-week-old colonies using double-sided cellotape and mounted in 3% KOH. Mean dimensions for conidia of *H. araucariae* were 7.6 x 5.3 μm (range: 5–16 x 3–13.5 μm; width/length ratio: 0.69) and for *H. annosum* 5.3 x 4.2 μm (range: 3.5–8.5 x 2.5–6.5 μm; width/length ratio: 0.79). Differences between the two species are highly significant ($p < 0.001$) for mean length (SED = 0.16), width (SED = 0.13), and width/length ratio (SED = 0.01). The dimensions obtained for conidia of *H. annosum* are close to those reported by Stalpers (1978), 4–8(–10) x 2.5–5(–6) μm, but are larger than measurements given by Courtois (1972), 3.8–5.2 x 2.9–3.9 μm, and smaller than those of Korhonen (1978), mean 5.9 x 4.2 μm for P-intersterility group and 6.8 x 5.1 μm for S-group; Stenlid & Häggblom (1985) reported mean size of S-group conidia as 5.3 x 3.6 μm. The relative intersterility group of the 3 strains of *H. annosum* used in the present study is not known. For some fungal species there is a close relationship between spore size and nuclear volume (Tolmshoff, 1983). Considering that *H. annosum* and *H. araucariae* are closely related species, the larger conidia of *H. araucariae* might indicate a polyploid origin.

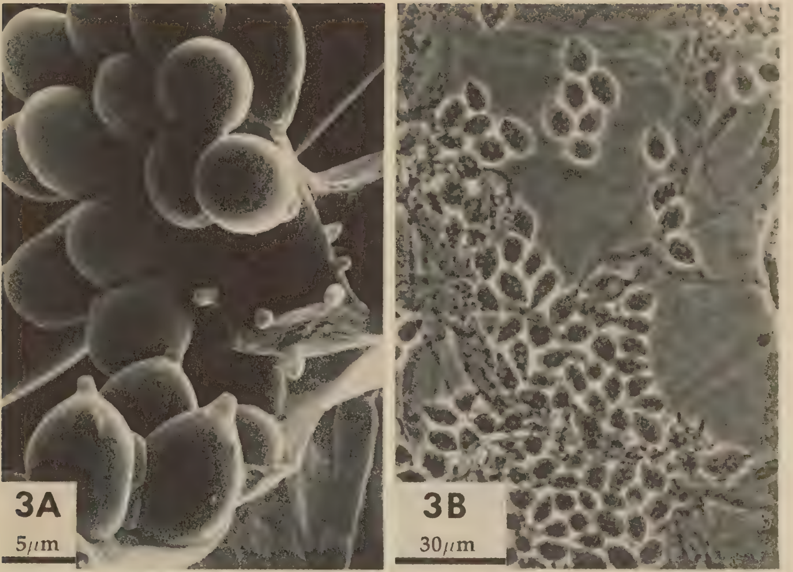
In other respects, cultures of *H. araucariae* are morphologically similar to those of *H. annosum*. Colonies of both species are typically white, farinaceous, with a *Spiniger* anamorph. Temperature optima and growth rates are similar. Hyphae are alike; sulphopositive hyphae bearing short papillate side branches, as described by Gluchoff-Fiasson et al. (1983) from cultures of *H. annosum* and *H. insulare*, also occur in *H. araucariae* (Fig. 2a).

Strains of *H. araucariae* and *H. annosum* can also be differentiated at the biochemical level. In a comparative electrophoretic study (unpublished data) the two species showed different alleles at two of four loci assessed, and marked differences in allele frequency at a third locus.

The name *Spiniger* is applied to oedocephaloid anamorphs of several species of basidiomycetes, although anamorph binomials have been published for only two of these species (Stalpers, 1974). It is considered inappropriate to publish a binomial for the anamorph of *H. araucariae*. In a key to the genus *Spiniger* (Stalpers, 1974), *H. araucariae* would key out beside *H. insulare* and *S. meineckellus* (A.J. Olson) Stalpers, the anamorph of *H. annosum*.

H. araucariae is homothallic. A survey of 43 single spore strains derived from 6 New Zealand collections showed the presence of clamped hyphal septa in all strains, although clamps were often rare and easily overlooked. Korhonen (1978) and Chase et al. (1985) reported homothallism for 3 Australian collections, and J.A. Simpson (pers. comm.) noted that single spores isolated from material collected in Papua New Guinea germinated to give clamped mycelium. In contrast, *H. annosum* is heterothallic with unifactorial incompatibility (Korhonen, 1978; Chase & Ullrich, 1983).

Two intersterility groups within northern hemisphere isolates of *H. annosum* were identified by Korhonen (1978) but 11 strains of *'H. annosum'* from Australasia did not mate with either group. Subsequently, Chase et al. (1985)


3A
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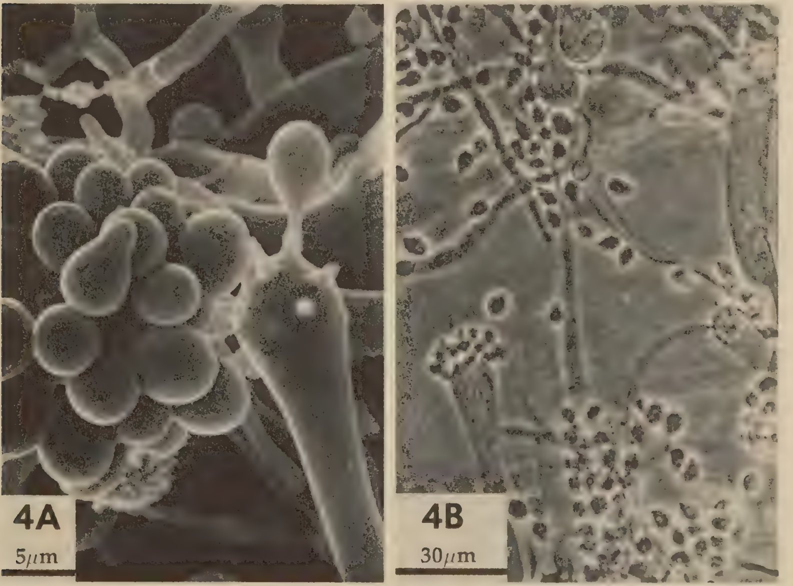
30μm


4A
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4B
30μm

Fig. 3. *Heterobasidion araucariae*, conidiophores and conidia: (A, ICMP 9529; B, ICMP 9534). **Fig. 4.** *Heterobasidion annosum*, conidiophores and conidia: (A, ICMP 9541; B, ICMP 9546).

reported heterokaryon formation between auxotrophic mutants of Australian *'H. annosum'* and some heterothallic auxotrophs of North American *H. annosum*. The possibility that gene flow may occur between strains of *H. araucariae* and *H. annosum* is being investigated by J. Stenlid (pers. comm.). In the light of other differences between the two taxa however, the demonstration of compatibility *in vitro* is not considered to negate arguments for the separation of *H. araucariae* from *H. annosum*.

The known hosts for *H. araucariae* are 2 species of *Agathis*, 2 species of *Araucaria*, and 3 species of *Pinus*. Most collections of basidiocarps are from stumps or dead wood. In New Zealand the fungus most commonly fruits on the trunk and branches of large fallen trees of *Agathis australis* (kauri), and on large, fallen branches shed from apparently healthy trees. It is reported to cause a sap rot of minor importance on living kauri (Gilmour, 1966). All known collections of basidiocarps on Pinaceae are from dead trunks, stumps, or logs. In northern New Zealand, on land cleared of kauri and replanted with several exotic species of *Pinus* known to be susceptible to *H. annosum*, *H. araucariae* has been recorded only on dead logs of *P. taeda*. In northern Queensland, basidiocarps of the fungus occurred on dead standing trees of *Pinus patula* in a stand showing high mortality, but it was not identified as the cause of death (Shain & Bolland, 1974). Although recorded on dead *Araucaria cunninghamii* in Papua New Guinea (Simpson, 1978), *H. araucariae* was not found on *P. caribaea* Morelet and *P. patula* in adjacent plantations.

Extensive plantations of *Pinus radiata* D. Don and *Pseudotsuga menziesii* (Mirb.) Franco occur throughout New Zealand. In the northern hemisphere, both species are susceptible to *H. annosum* (Gibson, 1979; Browne, 1968), but no *Heterobasidion* species has been recorded on either *Pinus radiata* or *Pseudotsuga menziesii* in New Zealand. Sutton (1965) offered the hypothesis that competition from *Phlebiopsis gigantea* (Fr.) Jül. could explain the non-pathogenic character of *'H. annosum'* in New Zealand. However, pathogenicity tests using one-year-old *Pinus taeda* seedlings in a glasshouse showed that New Zealand and Australian strains (labelled *H. annosum*) were less virulent than strains from the northern hemisphere (Kuhlman, 1970). *H. araucariae* is considered to be a saprophyte or weak pathogen with a restricted host range, unlike *H. annosum* which is pathogenic on many coniferous hosts and other trees (Browne, 1968). Recognition of the taxonomic distinction and difference in pathogenicity between *H. annosum* and *H. araucariae* has important implications for quarantine. The introduction of *H. annosum* to Australasia could threaten health of exotic and endemic conifers and other susceptible species.

H. araucariae might be expected to occur on other Araucariaceae and in other parts of the geographic range of the family, which extends from Indochina through Indonesia and Philippines to Australia, New Zealand, and the Pacific Islands, and in South America from Brazil to Chile (Willis, 1973). Material of *H. annosum* reported from Malaysia and Vietnam (Anon., 1980) has not been examined; Parmasto (1986: 64) lists *H. annosum* from Vietnam but states "possibly erroneous identification". *H. annosum* has been reported on members of the Dipterocarpaceae in the Philippines (Eusebio, 1977). In Indochina, the northern limit of Araucariaceae, *H. annosum* and *H. araucariae* could possibly occur together. Neither species has been definitively recorded from South America (J.E. Wright, pers. comm.; Anon., 1980). On Norfolk Island *H. araucariae* was not found on the endemic *Araucaria heterophylla* (Salisb.) Franco (personal observation).

The third species accepted in the genus *Heterobasidion*, *H. insulare*, can be readily distinguished from *H. araucariae*. Pilei of *H. insulare* are typically imbricate, small (2.5–9 cm across, 1.5–7 cm radius, 0.2–1.0 cm thick) and coloured red, dark red or reddish brown on the pileus surface, often with a cream margin. The pore surface has smaller pores, 2–3(–4) per mm, with dissepiments often thin and pores sometimes tending irpicoid towards the base of the basidiocarp. Basidiospores measure (4.5–)5–6(–7) x (3.5–)4–5 μm. *H. insulare* is a saprophyte, confined to Asia (India, Nepal, Burma, Japan, Philippines).

Key to species of Heterobasidion:

1. Pileus surface red; pores irpicoid to entire; Asian species; growing on dead wood — *H. insulare*
   Pileus surface brown; pores entire; on dead or living wood — 2

2. Pores 1–2(–3) per mm; spores 4.7–8.3 x 3.7–6 μm; southern hemisphere species — *H. araucariae*
   Pores 2.5–6 per mm; spores 4–6 x 3.2–4.5 μm, northern hemisphere species — *H. annosum*

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HYPHOMYCETES FROM CANADIAN STREAMS.
I. BASIDIOMYCETOUS ANAMORPHS

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Abstract

Fibulotaeniella canadensis gen. et sp. nov. and *Taeniospora nasifera* sp. nov. are described. *Taeniospora gracilis* var. *gracilis*, and *T. gracilis* var. *enecta* with an isolate having single-branched conidia are discussed. A presumable monocaryotic isolate of *Taeniospora descalsii* is reported.

Introduction

During a study focused on the isolation of freshwater hyphomycete taxa from foam on several softwater streams in SE New Brunswick and adjacent areas in Nova Scotia, a relatively high number of conidia with clamp connections were encountered. All these forms were obtained in pure culture; two are here described as new, two can be assigned to the newly described varieties of *Taeniospora gracilis* Marvanová (Marvanová & Stalpers 1987) and one is presumed to represent a monocaryotic *Taeniospora descalsii* Marvanová & Stalpers. Some of these conidial basidiomycetes are known to have a teleomorph belonging to the Athelieae, a subtribe of the Corticiaceae (Homobasidiomycetes), which are considered to be restricted to the Northern Hemisphere and particularly common in the boreal zone (Juelich 1972).

Materials and Methods

All cultures were obtained as monoconidial isolates from freshly collected stream foam. A few drops of antibiotic solution (100 mg penicillin and 100 mg streptomycin per liter acetone) were sometimes used to suppress bacterial contaminants. The cultures were maintained on 1.5 % Difco Malt Agar (MA) at 9 °C, or at 12 °C on sterile lupine (*Lupinus perennis*) stems partly embedded in 2 % water agar, or on sterile oat flakes in water agar.

Sporulation was induced by submerging a section of the culture in standing or aerated distilled water at 9-12 or 15 ° C. Septal pores were stained with Talbot's ammoniacal Congo Red (Nawawi et al. 1977). Nuclei were stained as follows: Conidia were harvested from one month old sporodochia on agar, suspended in distilled water, stained with a few drops of acridine orange and centrifuged; after washing once with distilled water, the conidia were observed under a Zeiss epifluorescence microscope. Nuclei were bright yellow-green. Alternatively, the nuclei were placed in Carnoy's fixative for 15 min., washed in conc. ethanol and in distilled water, and stained with Giemsa solution for 30 min. Laccase and tyrosinase tests were performed as described by Stalpers (1978).

Fibulotaeniella Marvanová et Bärlocher, gen. nov.

Etym.: *fibula* (L.) = clamp; *taeniella* (L.), diminutive of *taenia* = ribbon.

Deuteromycetes, Moniliales. Hyphae hyalinae, ramificatae, septatae, septa primaria fibulata, doliporosa, cellulae binucleatae. Conidiophora in conidiomatis sporodochialibus aggregata vel singularia ad hyphas, praecipue lateralia, simplicia vel ramosa. Cellulae conidiogenae in conidiophoris incorporatae, indeterminatae, elongationes sympodiales. Conidia scolecoidea, continua vel cum septo uno fibulato centrali in conidiis liberatis occurente. Dehiscentia schizolytica.

Species typica: *Fibulotaeniella canadensis*

Hyphae hyaline, branched, septate, clamped, cells binucleate, septa doliporous. Conidiophores aggregated in sporodochial conidiomata or scattered on hyphae, mostly lateral, simple or branched. Conidiogenous cells integrated or discrete, indeterminate, elongations sympodial. Conidia scolecoid, continuous or with a clamped septum near the middle appearing after conidium release. Secession schizolytic.

Fibulotaeniella canadensis Marvanová et Bärlocher, sp. nov. (Figs. 1, 2)

Coloniae in agaro maltoso lente crescentes, albidae, in senectute dilute sordide fuscae, pubescentes; mycelium aereum humile, funiculos delicatos formans. Odor penetrans. Hyphae marginales plus minusve rectae, 1.8-2.5 µm latae, cellulae usque ad 100 µm longae, rami alternati, raro suboppositi, supra basim saepe fibulati, e hypha vel raro e fibula crescentes. Septa secundaria in partibus senectis coloniae praesentia. Conidiophora praecipue lateralia, postea plerumque ramosa, usque ad 50 µm longa, prope basim fibulata, saepe in conidiomatibus densiter aggregata, vel singularia, continua vel multicellularia, cellulae cylindricae vel subfusoideae, septa fibulata. Cellulae conidiogenae singulares vel aggregatae usque ad tres, deinceps ecrescentes, supra basim fibulatae, fibulae conidiophori saepe suboppositae, raro e fibula oriuntur; initio continuae cum primordiis conidiorum, postea per septum fibulatum ab iis divisae, subfusoideae, 7-13 x 1.8-2.2 µm, apice saepe cum vestigiis fibularum ornatae, elongationes saepe fibulis oppositae, raro ex iisdem oriuntur. Conidia saepe in guttulis mucosis aggregata, sed singulariter oriunda, apicalia, basi fibulata, continua vel cum septo uno fibulato centrali tarde post liberationem apparente, arcuata vel sigmoidea, cylindrica, 47-85 x 2-3 µm, basi truncata, apice

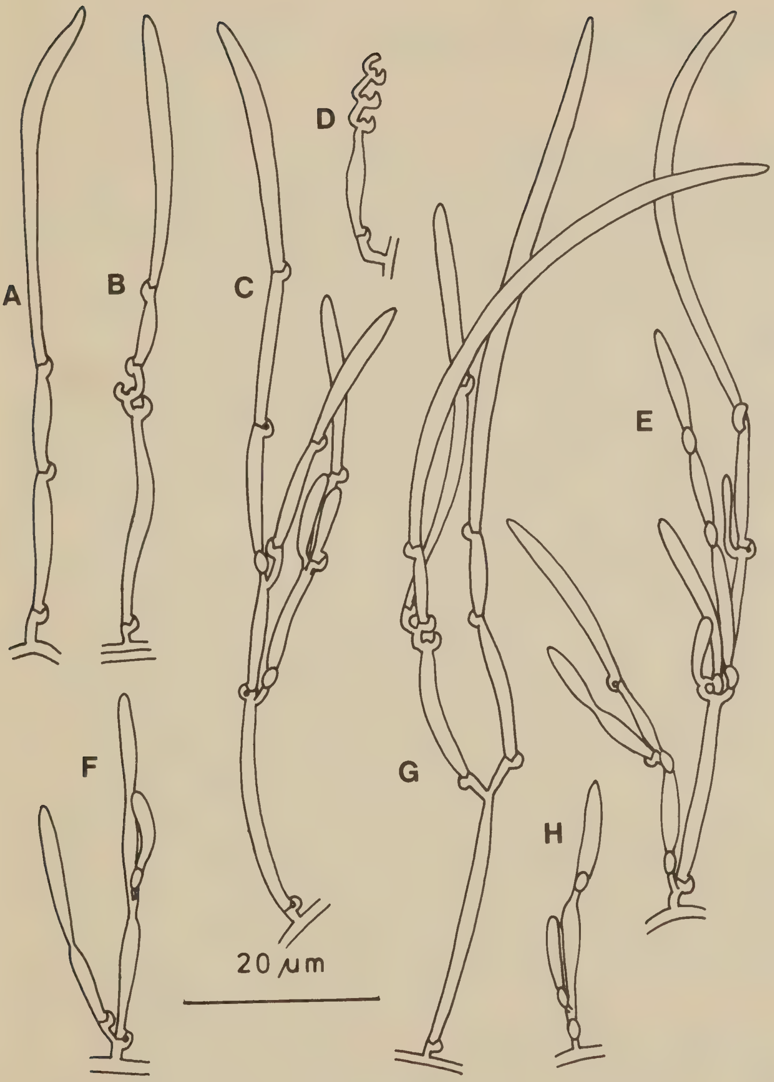
A
B
C
D
E
F
G
H
20 µm

Fig. 1. *Fibulotaeniella canadensis*, 12387. A-C, E-H, conidial ontogeny in culture; D, spent conidiophore.

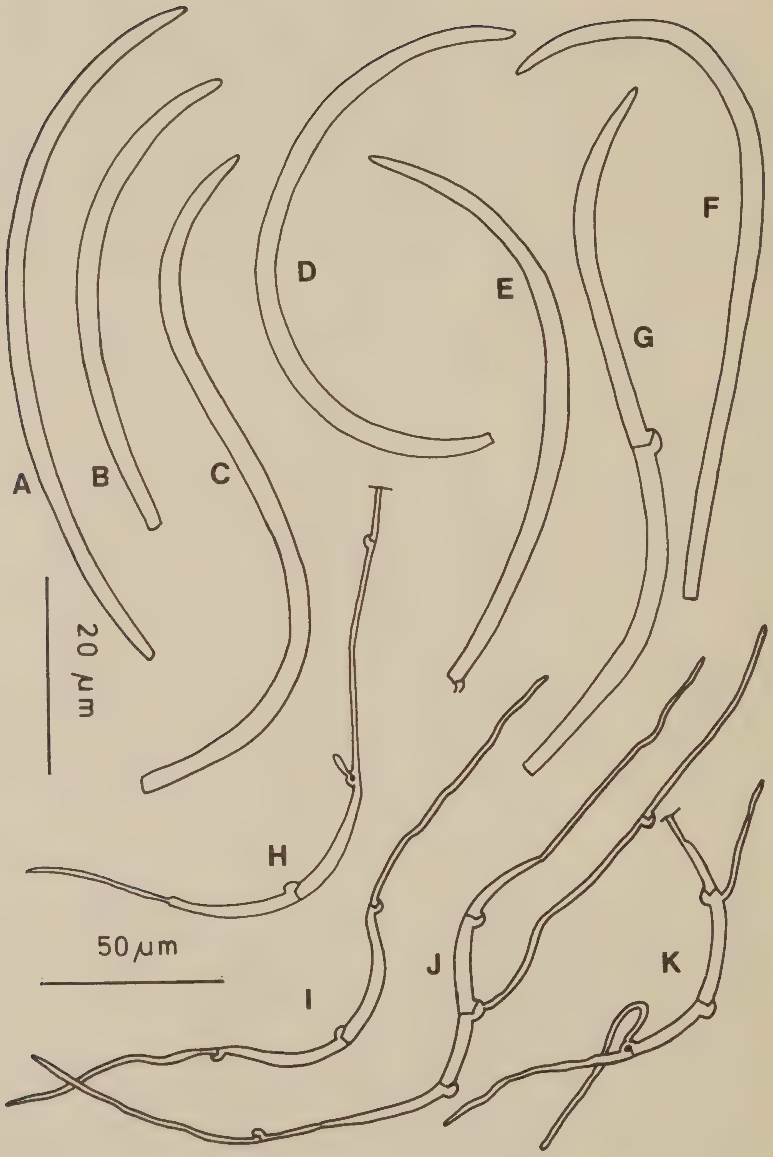
A
B
C
D
E
F
G
H
I
J
K
20 µm
50 µm

Fig. 2. *Fibulotaeniella canadensis*, 12387. A-F, detached, H-K germinating conidia; G, clamped conidium from foam.

subulata, binucleata ubi continua.

Habitat: In spuma in rivulo acido Allen Creek dicto, prope locum Wood Point, provincia New Brunswick, Canada austro-orientalis, in Aprili 1987 leg. L. Marvanová et F. Bärlocher.

Holotype: **K** (ex 12387).

Colonies (MA) growing slowly, 4 mm diam./21 days/10-12 °C, whitish, becoming pale isabelline with age, especially when submerged, reverse pale; aerial mycelium low, downy, white, covering the whole surface of the colony, forming delicate hyphal strands. Odor pungent, mushroom-like, becoming apparent when the colony is cut, resembling that of *Taeniospora gracilis*. Laccase test negative, tyrosinase weakly positive. Marginal hyphae more or less straight, 1.8-2.5 µm wide, cells up to 100 µm long, branches alternate, rarely subopposite, usually clamped near the base, originating from the hypha or rarely from a clamp. Secondary septa present in older parts of the colony. Sporulation in slime drops on agar or lupine stems, also in standing or aerated distilled water, under water or at the water-air interface. Conidiophores mostly lateral, densely packed in conidiomata or single, mostly becoming profusely branched with progressing conidiogenesis, pseudodichotomous branching sometimes seen at the lowest level; up to 50 µm long, but often shorter, continuous or multicellular, cells cylindrical or subfusoid, septa fibulata. Conidiogenous cells single or up to three at a conidiophore apex, appearing in a close sequence, clamped near the base, initially integrated with the conidial primordia, the point of the future delimiting septum often being marked with a shallow depression (Fig. 1 E, F), subfusoid, 7-13 x 1.8-2.2 µm, elongations originating slightly below and opposite to the basal clamp of the preceding conidium (rarely from the clamp itself); together with the clamp vestiges resembling connected wrenches (Fig. 1 D). Conidia aggregated in slimy drops or even masses but originating singly and apically, with a clamp at the base. Detached conidia are sigmoid or arcuate, 47-85 x 2-3 µm, cylindrical, with a truncate base and a subulate apex, exceptionally bearing a clamp vestige at the base (Fig. 2 E), in vitro remaining continuous even when suspended in water for several weeks, but with a central clamp typically present on the conidia collected in the field (Fig. 2 G), binucleate when continuous, nuclei usually near the middle or each in one half. Germination of conidia is accompanied by formation of one central and eventually two further clamps, one each near the two ends. The central clamp in arcuate conidia usually faces the concave side. First germ tubes emerge from the conidial ends, the subsequent ones from the conidial clamps or body.

Cultures examined: 12387, from Allen Creek, April 1987, isol. L. Marvanová; 14387, 14687, from St. George Creek, April 1987, isol. L. Marvanová; 22587, from a small stream near the Trans Canada Highway near Sackville, April 1987, isol. L. Marvanová.

All isolates were obtained from conidia bearing one clamped septum near the center. Nevertheless, only continuous conidia were formed in vitro in standing or aerated culture; when kept in water for several weeks, the conidia swelled considerably. Clamped septa on the conidial body appearing immediately before germination on agar (Fig 2, H-K). Conidia germinated more readily and germ tubes were more vigorous when a mixture of conidia from two isolates was used.

Free conidia in foam are easily recognized by the clamped septum in their center. However, clampless conidia should be expected in nature as well, but these probably escape recognition as basidiomycetous propagules, when identification is based exclusively on free conidia. Most likely they would resemble some *Flagellospora* or *Sigmoidea* spp.; however, all members of these genera have typically septate conidia except *F. penicillioides*, where some conidia may be continuous and overlap in length with those of *Fibulotaeniella canadensis*. However, *F. penicillioides*, as a species of warmer climates, would probably not appear in cold areas.

Without teleomorph, it may be too speculative to discuss the affinity of *F. canadensis* to other conidial basidiomycetes known from water; however, the presence of a single clamp in the conidia, the type of conidiogenesis and the colony characters (especially the odor) point to *Taeniospora*, namely *T. gracilis* var. *enecta*, which has spreading colonies and rather large conidia. However, the lack of branches in the conidia of our isolates and the sporodochial character of the conidiomata producing conidia in slime mass justifies the separation at the generic level.

Early stages in the conidiogenesis of the coelomycetous basidiomycete *Fibulocoela indica* Nag Raj (1978) and of *Cenangiomyces luteus* Dyko & Sutton (1979b) resemble the conidial primordia of *Fibulotaeniella*. However, the mature conidia of the first two species bear an apical (rarely also a basal) appendage. The conidiomata of *Fibulocoela* and *Cenangiomyces* are delimited by a distinct wall from the host tissue.

There is another coelomycete with more similar conidia, i.e. *Pocillopycnis umensis* (Bubák & Vleugel) Dyko & Sutton (1979a), with lunate conidia 60-81 x 3-4 µm; however, mature conidia are septate, the conidiogenous cells and conidia are clampless and the conidiomata are typical pycnidia (DiCosmo 1980).

Taeniospora nasifera Marvanová et Bärlocher, sp. nov. (Figs. 3, 4).

Etym.: *nasifera* (L.) = bearing a nose (refers to the shape of conidia).

Coloniae in agaro maltoso admodum lente crescentes, restrictae, pallidae, pulvinatae, leviter farinosae, mycelium aereum sparsum, e cellulis inflatis, 20-35 x 5-10 µm, catenatis vel aggregatis valde consistens. Odor penetrans. Hyphae marginales undulatae, 1-2 µm latae, cellulae usque ad 70 µm longae, rami alternati, e hypha crescentes, praecipue late divergentes, breves. Septa primaria fibulata, doliporosa, septa secundaria efibulata. Cellulae binucleatae. Conidiophora apicalia vel lateralia, solitaria, simplicia vel ramosa, usque ad 45 µm longa, septata, septa

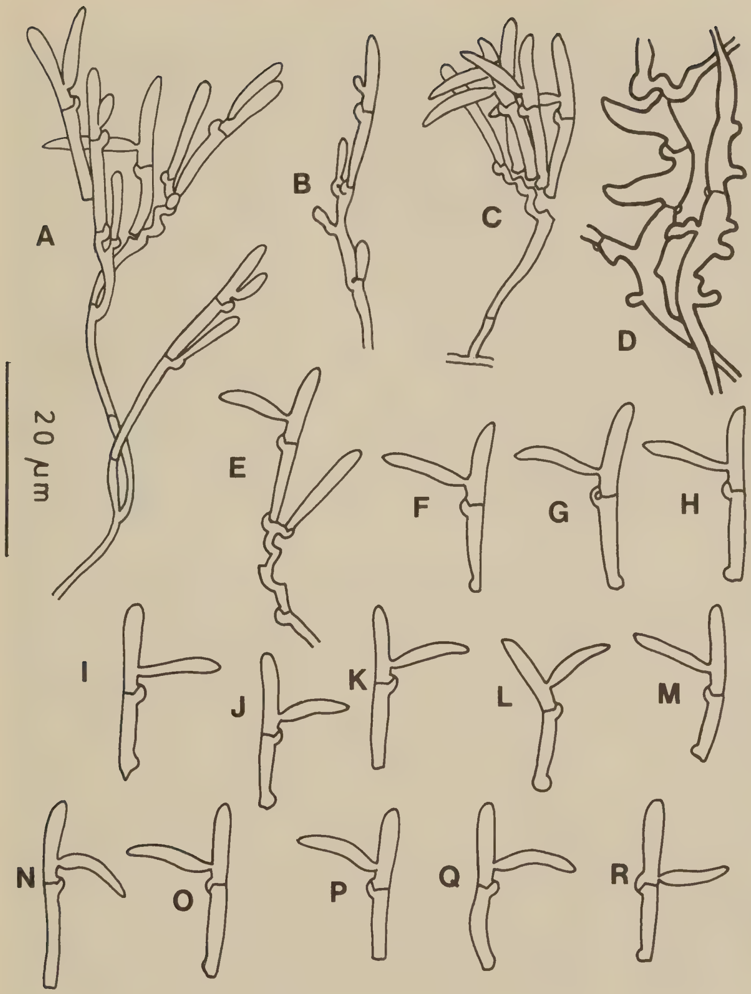
A
B
C
D
20 µm
E
F
G
H
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Fig. 3. *Taeniospora nasifera*, 14887. A-C, E, developing conidia from culture; D, inflated cells in mycelium; F-R, detached conidia.

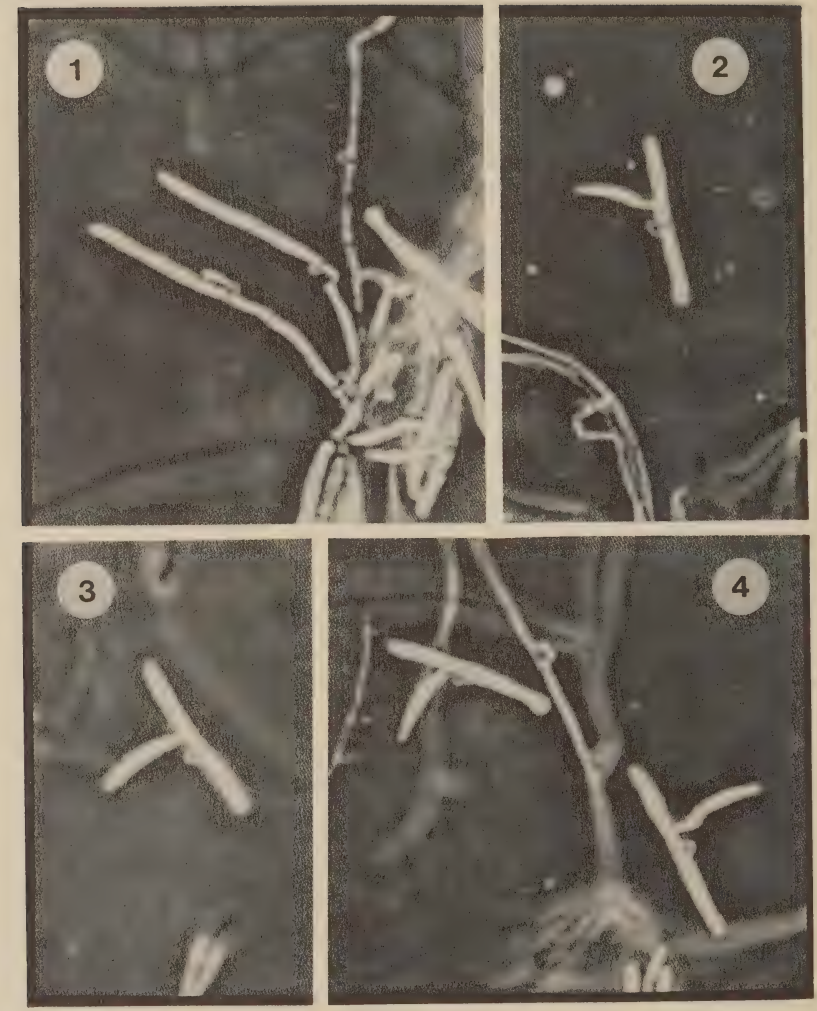

Fig. 4. *Taeniospora nasifera* 14887. 1, developing conidia. 2-4, detached conidia. Stained with lactofuchsin, photographed in inverted phase contrast light (approx. 1,200 x).

efibulata. Cellulae conidiogenae apicales vel raro laterales, singularies vel nonnullae basi saepe fibulatae, 7-10 x 2-3 µm, indeterminatae, elongationes sympodiales, e fibulis basalibus conidiorum precedentium oriuntur, rhachim flexuosam formantes. Conidia apicalia, plerumque fasciculata, basi fibulata, axis rectus vel paulo flexus, cylindricus vel subclavatus, 14-22 x 2-2.5 µm, basi pediformis , apice subulatus vel obtusus, septum unum fibulatum in parte centrali gerens. Ramus singulus, horzontalis vel leviter antrorsus, 7-10 x 1-1.5 µm, supra septum centralem axis insertus, sublunatus vel suballantoideus, basi angustatus, continuus.

Habitat: in spuma in rivulo acido St. George Creek dicto, haud procul a loco Fenwick dicto, in provincia Nova Scotia, Canada austro-orientalis, in Aprilis 1987 leg. L. Marvanová et F. Bärlocher.

Holotype: K (ex 14887).

Colonies on MA restricted, pulvinate, growing very slowly, 5 mm diam./40 days/15 °C, pale beige, mealy, aerial mycelium sparse, low, mostly consisting of short chains or clumps of inflated cells, reverse pale beige. Odor pungent, mushroom-like, resembling that of *Taeniospora gracilis*. Laccase test negative, tyrosinase test weakly positive. Marginal hyphae undulate, 1-2 µm wide, cells up to 70 µm long, branches alternate, short, growing from the hyphae, sometimes with a clamp near the base, broadly diverging. Primary septa with clamps, doliporous, secondary septa frequent. Cells binucleate. Inflated cells variously shaped, 20-35 x 5-10 µm, often with lateral comb-like outgrowths, septa often clamped, but clamps obscured due to deformations by inflation. Sporulation rapid after submersion (in 1-2 days), at or below water level. Conidiophores apical or lateral, branched or simple, without clamp at the base, 7-45 x 1-1.5 µm, stalk septate, but septa mostly clampless; conidiogenous cells apical or rarely lateral, single or several, 7-10 x 1-2 µm, with or without clamp at the base, indeterminate, elongations sympodial, originating from the basal clamps of the preceding conidia, forming a staircase-like rachis (Fig. 3 A, C). Conidia apical, appearing in close sequence, mostly fasciculate, delimited with a clamped septum. Detached conidia consist of a straight or slightly bent axis, cylindrical or subclavate, 14-22 x 2-2.5 µm, with a single, fibulate septum near the center, base truncate or more often foot-shaped; apex subulate or obtuse; branch single, horizontal or slightly antrorse, 7-10 x 1-1.5 µm, inserting in the distal half of the axis just above the central septum, usually facing the same side as the clamp, slightly lunate or allantoid, continuous, insertion narrow, without septum. Germination on agar, at 15 °C, after 48 hours, first from the ends of the axis, later from the branch.

Cultures examined: 14887, 15887, from St. George Creek, April 1987, isol. L. Marvanová.

Sporulation which was abundant with primary cultures, ceased totally after the first transfer; however, it could be reinduced in cultures established from actively growing hyphal tips from the very edge of the colony; abundant conidiation was also observed on sterile oat flakes embedded in plain agar, after drying out and submersion in distilled water. Conidiophores with profusely branched heads were obtained with the latter method.

As with *Fibulotaeniella*, the generic classification of this species is not easy. The conidia with a straight axis and a single branch are not typical for *Taeniospora* and would justify establishing a new genus. Other features, however, make *Taeniospora* a suitable genus: the single clamp in the middle of the axis, a pale beige colony and the strong odor. The restricted growth of the colony, the inflated cells and the small dimensions of the conidia make this species more similar to *Taeniospora gracilis* var. *gracilis* than to *T. gracilis* var. *enecta*.

Taeniospora gracilis Marvanová (Figs. 5, A-G; 6, M-O).

The two varieties recognized within this species (*T. gracilis* Marvanová var. *gracilis* and *T. gracilis* Marvanová var. *enecta* Marvanová & Stalpers) were based on isolates from continental Europe and from Great Britain. Conidia of both varieties were encountered in this study, and after isolation they yielded the typical colonies described by Marvanová & Stalpers (1987), characterized by pungent odor. Conidia of var. *enecta* were reported by Bärlocher (1987) as *T. gracilis* from the same and similar localities.

Conidia closely resembling those of var. *enecta* (Fig. 5, D-G), except having only the proximal branch, were collected frequently in some of the investigated waters. The single isolate obtained was culturally almost identical with var. *enecta*, i.e. the colony was whitish, not restricted, downy, with delicate hyphal strands, hyphae with clamped septa. It produced a *Taeniospora*-like odor. However, double-branched conidia seen in aerated culture on lupine stems indicate that the conidia with one branch may merely be a depauperate morphotype of var. *enecta*, which appears naturally under unknown conditions. There is probably a basifugal sequence of branches in *T. gracilis* var. *enecta* (cf. Nawawi et al. 1977, for data on branch length, and Marvanová & Stalpers 1987, Fig 3 B), which makes production of such conidia likely. Accordingly, should single-branched conidia appear in *T. gracilis* var. *gracilis* which has a basipetal sequence of conidial branch formation, they can be expected to possess only the distal branch. In fact, such conidia were observed in 15487 and 25887.

Cultures examined: *T. gracilis* var. *gracilis*: 15487, St. George Creek, April 1987, isol. L. Marvanová; 25887, small stream on the left side of the Trans Canada Highway, near Ogden Mill Cross (Sackville), April 1987, isol. L. Marvanová.

T. gracilis var. *enecta* : 12287, Allen Creek, April 1987, isol. L. Marvanová. Isolate with single-branched conidia: 11787, Allen Creek, April 1987, isol. L. Marvanová.

Taeniospora descalsii Marvanová & Stalpers (Figs. 6 A-L).

This species was recently described from Great Britain and

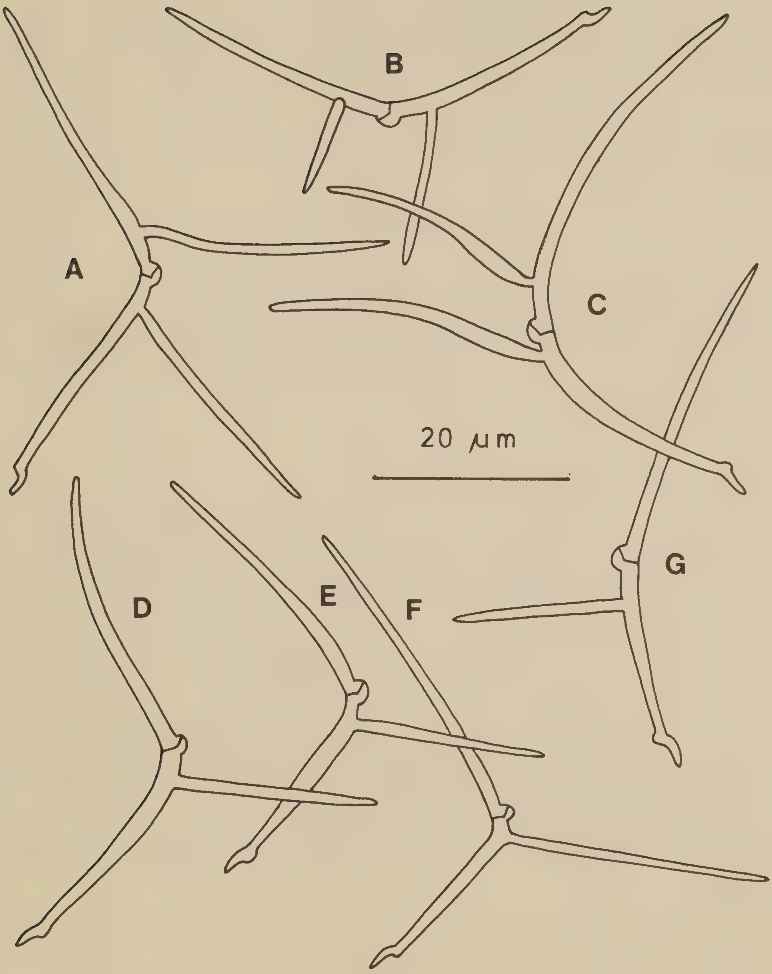

Fig. 5. *Taeniospora gracilis* var. *enecta*, 12287. A-C, typical conidia. *Taeniospora gracilis* var. *enecta*, 11787. D-G, single-branched conidia.

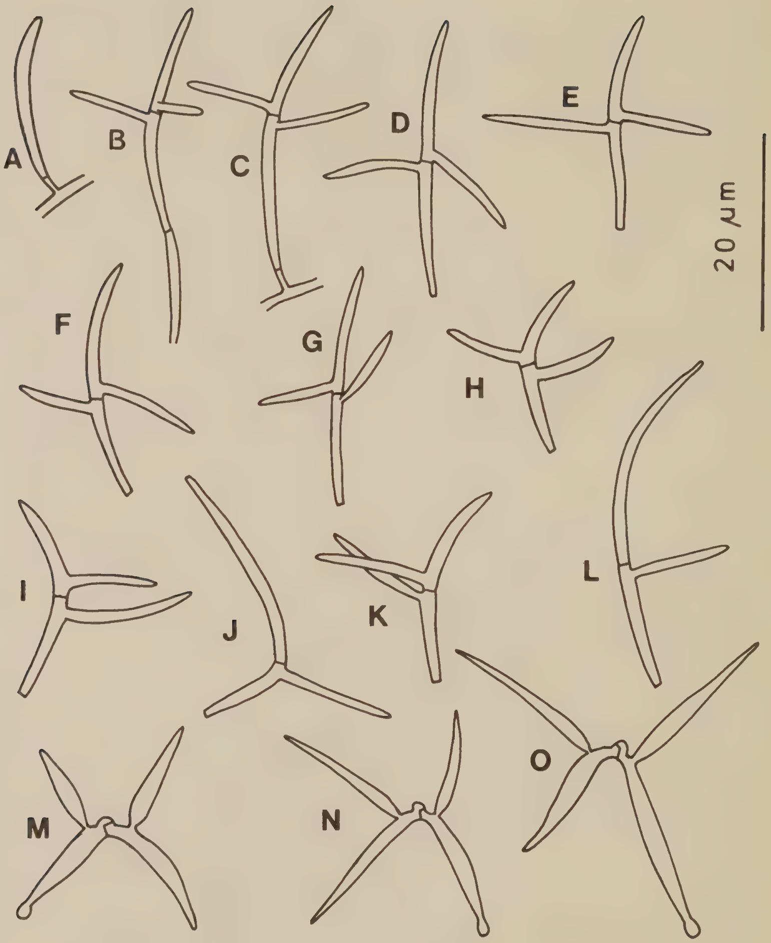
A
B
C
D
E
20 µm
F
G
H
I
J
K
L
M
N
O

Fig. 6. *Taeniospora descalsii* (?), monocaryon, 12787. A-C, developing conidia; D-L, detached clampless conidia. *Taeniospora gracilis* var. *gracilis*, 15487. M-O, detached conidia.

Czechoslovakia on the basis of three isolates (Marvanová & Stalpers 1987). During the present investigation, an isolate of presumably the same species was obtained from a clampless conidium which gave rise to a monocaryotic mycelium. The colony characters matched those of the above mentioned isolates. Mating experiments with the CCM dicaryotic strains could not be performed because the Canadian isolate did not survive the transport.

Culture examined: 12787, Allen Creek, April 1987, isol. L. Marvanová.

Acknowledgements

This research was supported by grants from the National Science and Engineering Research Council of Canada and the Donner Canadian Foundation. The senior author thanks Dr. A. Svoboda for the use of a phase microscope and Mr. Holubár for assistance with staining of the nuclei. Sincere thanks are due to Prof. R. J. Bandoni, University of British Columbia, for reviewing the manuscript.

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A NEW SPECIES OF HYALOSCYPHACEAE ON NEEDLES OF PICEA (PINACEAE)

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SUMMARY

A new species of Hyaloscyphaceae, Lachnum rubropunctatum, growing on needles of Picea A.Dietr. is described. A key to 8 species and one variety of Hyaloscyphaceae growing on needles and cones of Pinaceae is provided, including Cistella acuum (Alb. & Schw.)Rativ., Dasyscyphella conicola (Rehm)Raitv. & Arendholz comb. nov., Dasyscyphella mughonicola (Svr.)Raitv. & Arendholz comb. nov., Hyalopeziza trichodea (Phill. & Plowr.)Raitv., Incrupila alatavica Raitv., Incrupila dennisii (Müller)Müller, Lachnum pulverulentum (Lib.)Karst., Lachnum pulverulentum (Lib.)Karst. var. fructicola (Rehm)Arendholz & Raitv. comb. nov.

During a vacation trip in the Berner Oberland (Switzerland) in the summer 1977 the senior author collected a hairy Discomycete growing on dead, fallen spruce needles and which, after a thorough study of the literature and the reinvestigation of different type specimens, proved to be a new species.

LACHNUM RUBROPUNCTATUM Raitv. & Arendholz sp. nov.

Figs.: Plate 1, fig. 1-6; plate 2, fig. 1-3.

Apothecia cupulata, stipitata, perparvula, ad 0.2 mm diam., plusminusve alba, in sicco ochracea margine rufo. Excipulum et stipes pilosi, pili eseptati, raro uniseptati, leptodermi, hyalini ad dilute aurantiaci per microscopium; grosse granulosi per materiam resinaceam aurantiacam, diffluentes in KOH, ad marginem 35-45 x (5)-6-7.5 µm, ad excipulum et ad stipes breviores circiter (15)-20-25 x (4)-5-6 µm.
Excipulum ectalum ex textura prismatica ad textura intricata, cellulae hyalinae, leptodermae.
Excipulum medullatum ex textura intricata, cellulae hyalinae, leptodermae.
Asci cylindrcei-clavati, 21-28 x 3-4 µm, e uncis nati, poro jodo caerulescente.

Ascosporae hyalinae, eseptatae, ellipsoideae, 4-6.5 x 1.5-2 µm, partim habentes duae guttulae.
Paraphyses perparcae, 1.5-2.5 µm latae, cylindraceae, acutae, ad cylindracei-lanceolatae, ascos leviter superantes.

Holotypus.- In acibus Piceae abietis (L.)Karst., Wengen, regione Bernae montana, Alpes, Helvetia, alt. 1200 m, W.R. Arendholz, 7 Aug. 1977. In herbario W.R.A. 1977/40.

Apothecia cupulate, on a well developed short stipe, very minute, up to 0.2 mm in diam., ± white, ochraceous when dry, with a reddish margin.
Hairs cylindrical, 1-celled, very rarely 2-celled, originating from a ± cuboid basal cell, hyaline to pale orange under the microscope, thin-walled, coarsely granulate, covered by pieces of resinous matter dissolving in KOH, at the margin 35-45 x (5)-6-7.5 µm, at the flanks of the apothecium and at the stipe smaller, (15)-20-25 x (4)-5-6 µm.
Asci cylindric-clavate, with a short, definite stipe, sometimes sessile, arising from croziers, with and without KOH pretreatment J+, 21-28 x (3)-4-5-(6) µm.
Ascopores hyaline, aseptate, ± ellipsoid, straight, sometimes somewhat tapering at the lower end, partly with two oil drops at each end.
Paraphyses very scanty, cylindrical, pointed to cylindrical-lanceolate, slightly exceeding the asci, 1.5-2.5 µm in diam.

Etymology of the specific epithet.- Refers to the colour of the apothecia in the dried condition.

Habitat.- On dead fallen needles of Picea abietis (L.) Karsten.

Type locality.- Wengen, Berner Oberland, Alps, Switzerland.

Holotype.- W.R. Arendholz, 7 Aug. 1977, in the senior author's personal herbarium, W.R.A. 1977/40.

Notes.-Lachnum rubropunctatum is macroscopically similar to Lachnum pulverulentum (Lib.)Karst. on fallen needles of Pinus, but the latter differs in having larger diameter, longer, narrowly cylindrical, apical swollen, always 3-4-celled hairs (50-60 x 3-3.5 µm) and larger ((28)-30-40 x 3-4 µm) asci.
According to the descriptions L. rubropunctatum also resembles Incrupila dennisii (Müller)Müller on Pinus cembra L. (MÜLLER 1967, 1977) and Dasyscyphus mughonicola Svr. on Pinus mugo Turra subsp. mughus (Scop.)Zenari (SVRCEK 1967), but the latter differs from our species by its colour (lemnon-coloured) and the apothecia (0.4-0.8 mm in diam.), marginal hairs (80-110 x 2-3.5 µm), asci (55-60 x 4.5-5 µm) and ascospores (8.5-11 µm) are without exception larger.
In contrast to D.mughonicola nearly all the measurement and characters of Incrupila dennisii correspond, according to the description, with L. rubropunctatum. But the com-

parison with the type specimen proved that the species are not conspecific: Incrupila dennisii differs from our species by its colour in the dried condition (whitish to honey coloured) and the hyaline and thin-walled, often 2-3-septate hairs show a still stronger incrustation, although in L. rubropunctatum the granular incrustation is relative strong and massive (cf. plate 1, fig. 4 and 6). It remains to be clarified, whether these species are congeneric, when we understand these minute, rough-haired hyaloscyphaceous taxa better. Finally it should be noted, that the hairs of Incrupila dennisii described by MÜLLER (1967) as 15-25 x 4-6 μm are actually up to 40 μm long and often 2-3-septate, which both authors ascertained by studiing the holotype species.
By having mostly aseptate hairs L. rubropunctatum also bears some resemblance to the species of Cistella, but its hairs are totally granulate, whereas the hairs of Cistella are granulated only apically or have at least a smooth basal part, 1/4 to 1/5 of the total hair length and are without an exudation.

Following is a key to determine species of the Hyaloscyphaceae on needles and cones of Pinaceae:

1 Hairs smooth, long (up to 240 μm) and thick-walled, on Pinus sylvestris L.(1)
HYALOPEZIZA TRICHODEA (Phill. & Plowr.)Raitv.
1* Hairs granulated.....................................2

2 Hairs totally granulated or with a smooth basal part 4
2* Hairs with completly smooth and ± clavate tips of various length......................................3

3 Asci 50-60 x 4.5-5.5 μm, spores fusoid, 8.5-11 x 2-3 μm, on Pinus sylvestris L., Pinus mugo Turra and Pinus cembra L. (2)
DASYSCYPHELLA MUGHONICOLA (Svr.)Raitv. & Arendholz comb. nov.
3* Asci 30-40 5-6.5 μm, spores elliptic-fusoid, 6-10 x 1.5-2.5 μm, on cones of Pinus sylvestris L. (3); plate 2, fig. 1.
DASYSCYPHELLA CONICOLA (Rehm)Raitv. & Arendholz comb. nov.

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(1) Synonyms: Dasyscypha triglitziensis Jaap, Trichopeziza marchica Kirschstein; for further synonyms cf. RASCHLE (1977).

(2) Basionym: Dasyscyphus mughonicola Svr., Ceska mykol. 21 (1967) 65.

(3) Basionym: Dasyscypha pulverulenta (Lib.)Sacc. var. conicola Rehm, Ann. mycol. 8 (1910) 492. D. conicola (Rehm)Raitv. & Arendholz differs from Dasyscyphella mughonicola (Svr.)Raitv. & Arendholz in shorter asci (45-50 x 6-6.5 μm) and ascospores (6.5-10 x 1.5-2.5 μm) and the absence of the bright yellow colour of the apothecia.

4 Hairs usually ± clavate, mostly with a smooth basal part (4)
CISTELLA ACUUM (Alb. & Schw.)Raitv.

4* Hairs totally granulated............................5

5 Asci 30-40 x 3-4 µm, spores cylindric-clavate, 4-7 x 1-1.5 µm; the ± red exudations on the tips of the hairs are soluble in ethanol, KOH and lactic acid; on Pinus sylvestris L., Pinus rigida (HAINES in litt.) and Abies alba Mill. (KANOUSE 1947); plate 2, fig. 2. (5)
LACHNUM PULVERULENTUM (Lib.)Karst.

5* Not with the above mentioned characters.............6

---

(4) *Cf. e.g. REHM (1893), RAITVIIR (1970), DENNIS (1949,1978), BREITENBACH/KRÄNZLIN (1981). Synonyms: Clavidisculum kriegerianum Kirschstein, Pezizella pulchella Fuckel, Helotium pulchella (Fuckel)Boud.; for further synonyms cf. DENNIS (1949) and SVRCEK (1962)*

SVRCEK (1983) claims, that REHM (1893) and DENNIS (1949) erroneously synonymized Pezizella pulchella Fuckel with Dasyscyphus (=Cistella) acuum (Alb. & Schw.)Sacc., and he states that evidently REHM did not know P.pulchella. SVRCEK bases his conclu- on FUCKEL's (1870) short description of this species, which he cites in part, and selects P.pulchella as the type species of the genus PEZIZELLA. During his work on a revision of this genus the senior author studied a syntype specimen of the species under discussion from Stockholm (ex herb. REHM), which proves without doubt the identity with Dasyscyphus (=Cistella) acuum (Alb. & Schw.)Sacc. Additionally the label of the type specimen includes notes in RHEM's handwriting, which show, that REHM did know P. pulchella.

Furthermore SVRCEK's typification is untenable, because BACHMANN (1909) previously typified PEZIZELLA with P. sordida Fuckel, long before v.HÖHNEL's (1926) typification and studies of this genus were published (ARENDHOLZ 1988).

During preparing this paper the senior author reinvestigated different specimens of Cistella acuum (Alb. & Schw.)Raitv. (cf. specimens examined) and found out, that the ± clavate hairs of the apothecia are totally granulated, which is clearly observed especially with DIC in the light microscope. Perhaps this character points more to a membership of this species to Lachnum (= Dasyscyphus) rather than to Cistella. Such hairs (somewhat more cylindrical) are e.g. figured by BREITENBACH/KRÄNZLIN (1981), and DENNIS (1949) and MATHEIS (1976) write:"...granulate, especially at the swollen tip,..."; "die Granulierung ist nicht immer auf den oberen Teil des Haares beschränkt. Teilweise (Apothecien der gleichen Nadel) ist auch das gesamte Haar zerstreut granuliert.... Vielleicht handelt es sich auch um eine Sammelart, die noch des näheren Studiums dedarf.", respectively. BARAL (1985) takes up the idea of an "inhomogenous" species, too, and he classified his finds by means of "subtiler Mikromerkmale", which, however, he does not explain in detail.

(5) *Synonyms: Dasyscypha pulverulenta (Lib.)Sacc. var. purpurescens Rehm; Ann. mycol. 8 (1910) 288; Trichopeziza eximia Mont. & Sacc.; cf. also e.g. REHM (1894), RAITVIIR (1970), DENNIS (1978).*

6 Hairs with ± amber coloured, birefringent exudations, which are insoluble in ethanol, KOH and lactic acid, on cones on Pinus sylvestris L. (6)
LACHNUM PULVERULENTUM (Lib.)Karst. var. FRUCTICOLA (Kauffm.)Arendholz & Raitv. comb. nov.

6* Hairs not with ± amber coloured, birefringent exudations..7

7 Hairs one-, rarely two-celled, (15)20-45 x 5-7 µm, apical covered by pieces of resinous matter dissolving in KOH, on Picea abies (L.)Karst.; plate 1, plate 3.
LACHNUM RUBROPUNCTATUM Raitv. & Arendholz sp. nov.

7* Hairs apical without pieces of resinous matter, but densely incrusted with large granules of hyaline amorphous matter..8

8 Ap. shortly stipitate, 0.3-0.5 mm in diam., hairs 30-50 x 3-5 µm aseptate, Asci 27-30 x 3-4 µm, spores clavate-fusoid 5-8 x 1.5 µm; on Picea schrenkiana Fisch. & Mey. (7); plate 2, fig. 3.
INCRUPILA ALATAVICA Raitv.

8* Ap. shortly stipitate, 0.15-0.25 in diam., hairs up to 40 x 4-6 µm, often 2-3-septate, Asci 20-25 x 4.5-5 µm, spores 5-6 x 1.5-2 µm, on Pinus cembra L. (8)
INCRUPILA DENNISII (Müller)Raitv.

Besides those mentioned in the key above, some more hyaloscyphaceous species growing on dead, fallen needles of Pinaceae were described. Since their first description these names do not appear in the literature again, with the exception of the works such as REHM *(1887-1896)*, SACCARDO (1889), BOUDIER (1907) and VELENOVSKY (1934). The maintenance of these names as separate species is impossible by the interpretation of the often poor descriptions, and it remains to be reserved for a reinvestigation of the type specimens, as far as these still exist.
The main characters of these "species" are mentioned in a "key" below:

1 Ap. 3-4 mm in diam. Asci 80-100 x 5 µm, spores acicular 6-8 µm (VELENOVSKY 1934)
LACHNUM PICEUM Vel.

1* Ap. up to 1 mm or hardly reaching 0.5 mm in diam..............2

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(6) Basionym: Dasyscypha pulverulenta (Lib.)Sacc. var. fructicola Kauffm. Paper Mich. Acad. Sci. 1 (1923) 106.

(7) Cf. RAITVIIR (1981); this species is very closely related to Incrupila dennisii (Müller)Müller growing on fallen needles of Pinus cembra L. in the Alps. Both species can serve as an example of geographically vicarious sibling species. The Tien-Shan fungus differs from the Alpic species mainly in more slender, tapering hairs and in slightly longer asci.

(8) Cf. MÜLLER (1967, 1977).

2 Ap. up to 1 mm in diam., hairs up to 200 x 3-4 µm, sulphur yellow, granulate, flexible; (VELENOVSKY 1934) (9)
DASYSCYPHA PULVERULENTA (Lib.)Sacc. var.PICEICOLA Vel.

2* Ap. up to 0.7 mm or smaller than 0.5 mm in diam...............3

3 Ap. up to 0.7 mm in diam., spores acicular to fusoid, with oil drops, up to 10 µm, (10)
ERINELLA SERINELLA Quel.

3* Ap. smaller than 0.5 mm in diam...............................4

4 Ap. up to 0.3 mm in diam., asci 30-40 x 5-6 µm, spores acicular, 3-5 µm, (VELENOVSKY 1934)
LACHNUM ACICULARUM Vel.

4* Ap. 0.1-0.2 mm in diam., spores acicular to fusoid, 5 µm (QUELET 1884) (10)
ERINELLA PUBERULA Quel.

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(9) This variety is mentioned by BARAL & KRIEGELSTEINER (1985), but the affiliation of this find to this variety without studiing the type is somewhat speculative, especially since VELENOVSKY's description is rather empty. Furthermore he does not describe the clearly discernible (± red) exudations of the hairs, neither for the species nor for his variety, which are characteristic of Lachnum (= Dasyscyphus) pulverulentum.

(10) Neither in Paris nor in Uppsala exsiccata of these species are present. Only a variety of Erinella puberula Quel. (E. puberula var. abietis Quel.: France, Valles des Charbonniers, 25.5.1885, leg. Quelet) was available to the senior author. This specimen consists of a single needle of Picea abies (L.)Karst., on which one hairy, ± buff and stipitate apothecium (diam. about 0.5 mm, stipe about 0.6 mm long) and some stipes remain. Because of the scanty material no detailed microscopic studies were possible. The hairs are up to 100 x 4 µm, totally, fine granulate and 3-5-septate and somewhat tapering towards the tip; asci, spores and paraphyses not seen. Although no precise examination of the excipulum and the hymenium were practicable, it is rather clear, that this species is a member of the genus LACHNUM, which may be worth a species of its own, because it differs distinctly from all species mentioned in the key on page 355-357. But because of the insufficient material no new species was founded.

Plate 1

LACHNUM RUBROPUNCTATUM Raitviir & Arendholz sp. nov., W.R.A. 1977/40.

Fig. 1: Two apothecia shown from above, 150 x.
Fig. 2: A group of apothecia on a spruce needle, incident light, dark field, 30 x.
Fig. 3: Apothecium showing downy excipulum, SEM picture, 270 x.
Fig. 4: Some hairs of the excipulum showing resinous matter, 2800 x.
Fig. 5: Part of the stipe, showing hairs with resinous matter, 1500 x.
Fig. 5: Some hairs of the excipulum as seen under the light microscope, DIC (1), 1220 x.*
Fig. 6: The same as in fig. 4, but more enlarged, SEM picture, 7400 x.
Fig. 6: A hair from the stipe as seen under the light microscope, bright field, 1220 x.*
Photographs: Arendholz

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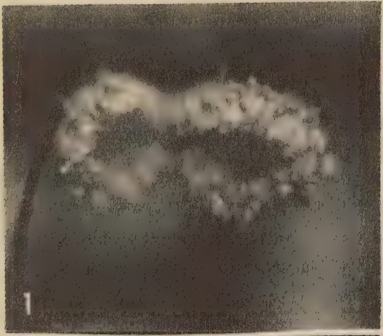
(1) DIC = Differential interference contrast according to NOMARSKI.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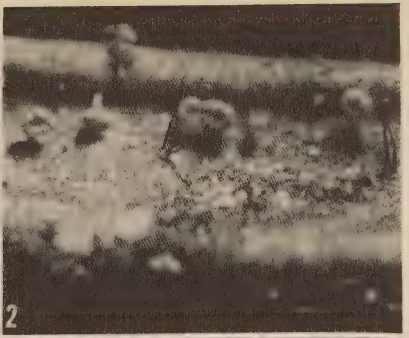
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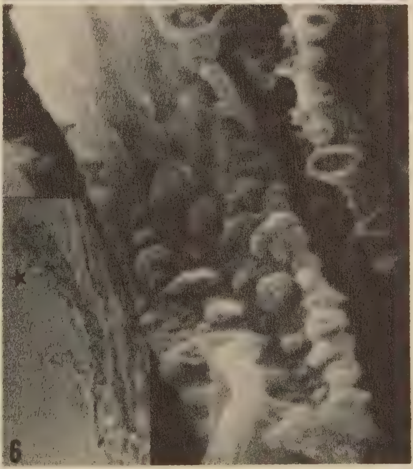
5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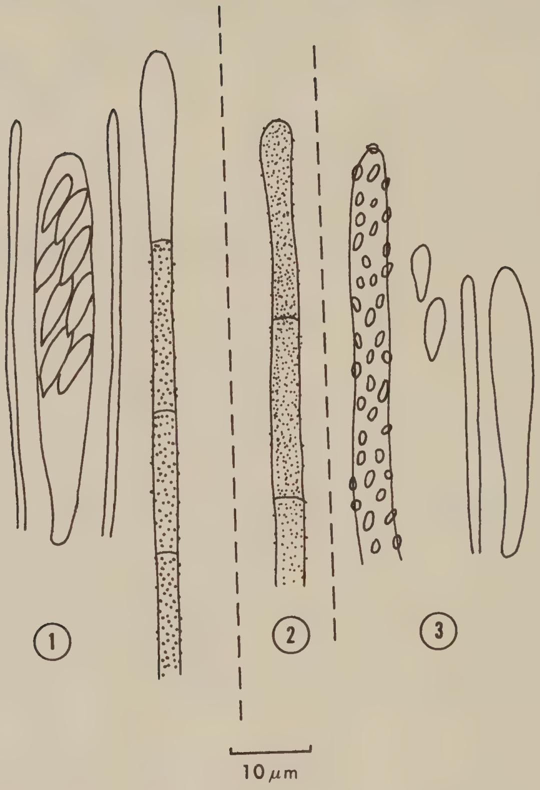

Plate 2

Fig. 1: *DASYSCYPHELLA CONICOLA (Rehm)Raitv. & Arendholz comb. nov. A hair, an ascus with ascospores and paraphyses; Sydow, myco. germ. 907, LE.*

Fig. 2: *LACHNUM PULVERULENTUM (Lib.)Karst.; a hair; from a collection by D. Benkert.*

Fig. 3: *INCRUPILA ALATAVICA Raitv.; a hair, an ascus, ascospores and paraphyses; holotype (TAA 63531a).*

Raitviir/Arendholz del.

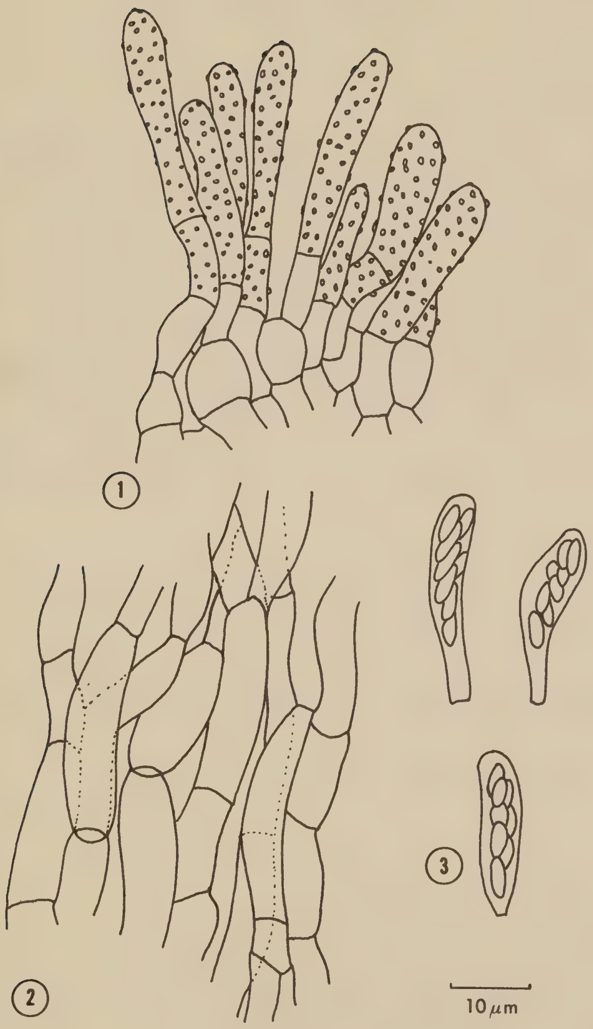

Plate 3

LACHNUM RUBROPUNCTATUM Raitviir & Arendholz sp. nov., W.R.A. 1977/40.

Fig. 1: Hairs at the margin.
Fig. 2: Part of the ectal excipulum.
Fig. 3: Three asci with ascospores.

Arendholz del.

Specimens examined

CISTELLA ACUUM (Alb. & Schw.)Raitv.

Habitat.- On needles of Abies alba Mill., Picea abies (L.)Karst. and Pinus sylvestris L.

1. Parc du Libiscy, January 1846; Plantes crypt. Fr. ed. I 1536 (HBG). 2. Im Östricher Wald, Frankensteiner Kopf, im Herbst; Fungi rhen. 1153 (G). 3. Bei Östrich, Frühjahr, Fuckel; Rabenh. F. europ. 1116 (HBG). 4. Östrich, im Herbst und Frühjahr, Fuckel; syntype of Pezizella pulchella Fuckel, F. rhen. 2077 (S). 5. Schweiz, Zürich, Herbst 1876, G. Winter (HBG). 6. Schöneberg/Berlin, April 1890, P. Sydow (HBG). 7. Großer Winterberg, Sächsiche Schweiz, September 1892, G. Wagner; Krieger F.sax. 884, Rehm Asc. 1054 (HBG). 8. Großer Winterberg, Sächsische Schweiz, August 1893, G.Wagner (HBG). 9. Brandenburg, Triglitz/Prignitz, März 1896, O. Jaap (HBG). 10. Königstein, Sächsische Schweiz, August 1902, W. Krieger; lectotype of Clavidisculum kriegerianum Kirschst. (B), isolectotype (HBG). 11. Brandenburg, Triglitz/Prignitz, April 1905, O. Jaap; Syd. Myc. germ. 598 (JE). 12. Grünauer Forst, Rathenow/Havel, Juni 1905, W.Kirschstein; Rehm Asc. 1054b (HBG). 13. Österreci, Sonntagberg, Rosenau, April (without year), P. Strasser; Kryptog. exs. 1442 (JE, HBG). 14. Brandenburg, near Beelitz, October 1934, H. Sydow; Sydow Myc. germ. 2946 (HBG).

DASYSCYPHELLA CONICOLA (Rehm)Raitv. & Arendholz

Habitat.- Cones of Pinus sylvestris L.
1. Brandenburg, Kupferhammer bei Mixdorf bei Müllrose, August 1909, P. Sydow, syntype of Dasyscypha pulverulenta (Lib.)Sacc. var. conicola Rehm; Sydow Myc. germ. 907 (HBG, LE). 2. Brandenburg, Triglitz/ Prignitz, October 1913, O. Jaap; syntype of Dasyscypha conicola Rehm in litt. 1895, nom. nud. (Dasyscypha pulverulenta (Lib.)Sacc. forma conorum Rehm in litt., nom. nud.); Jaap F. sel. exs. 676 (HBG) 3. R.S.F.S.R., Tambovskaya obliest, September 1928, A.S. Bondarzew (LE).

DASYSCYPHELLA MUGHONICOLA (Svrcek)Raitv. & Arendholz

Habitat.- On needles of Pinus cembra L., Pinus mugo Turra and Pinus sylvestris L.

U.S.S.R., the Sverdlowsk Region, the Ural mountains, October 1966, A. Sirko (TAA).

ERINELLA PUBERULA Quel. var. ABIETIS Quel. nom.nud.?

Habitat.- On needles of Picea abies (L.)Karst.

France, Valles des Charboniers, May 1885, Quelet (UPS).

HYALOPEZIZA TRICHODEA (Phill. & Plowr.)Raitv.

Habitat.- On needles of Pinus sylvestris L.

Brandenburg, Triglitz/Prignitz, October 1915, O. Jaap; syntype of Dasyscypha triglitziensis Jaap, Jaap F. sel.exs. 756 (HBG).

INCRUPILA ALATAVICA Raitv.

Habitat.- On needles of Picea schrenkiana Fisch. & Mey.

The Kazakh S.S.R., the Zailiiski Alautau Mountains (Northern Tien-

Shan), Dzhenischka, in the valley of the Kara-sha river, ca. 3000 m alt., June 1976, A. & M. Raitviir (TAA).

INCRUPILA DENNISII *(Müller)Müller*

Habitat.- On needles of Pinus cembra L.

Schweiz, Aletschwald, Belalpweg, September 1962, E. Müller, holotype of Dasyscyphus dennisii *Müller (ZT).*

LACHNUM PULVERULENTUM *(Lib.)Karst.*

Habitat.- On needles of Abies alba Mill., Pinus rigida Mill. and Pinus sylvestris L.

1. Boeckhorst, May 1861, Th. Sprée; Rabenh. F. europ. 514 (HBG). 2. Baden, Rastadt, Frühjahr 1877, Schröter; de Thümen Myc. univ. 917 (HBG). 3. Grunewald/Berlin, May 1885, P. Sydow; Syd. Myc. march. 781 (HBG). 4. Brandenburg, Tamsel, April 1905, P. Vogel; Rehm Asc. 1730, Syd. Myc. germ. 606 (HBG). 5. Klosterfelde bei Lichtenwalde, June 1905, H. Sydow (HBG). 6. Brandenburg, Triglitz/Priglitz, July 1908, O. Jaap; Rehm Asc. 1877 (HBG). 7. Potsdam, May 1973, D. Benkert (TAA). 8. Belgium, Liege, no date, presumed holotype of Trichopeziza eximia *Mont. & Sacc. (PAD).*

LACHNUM PULVERULENTUM *(Lib.)Karst. var.* FRUCTICOLA *(Kauffm.)Arendholz & Raitv.*

Habitat.- On cones of Pinus sylvestris L.

Tolland, Colorado, September 1920, C.H. Kauffman, holotype (MICH).

ACKNOWLEDGEMENTS

The authors are pleased to acknowledge the constructive comments of Dr. J.H. Haines, New York State Museum. Furthermore they are deeply indebted to the directors and curators of the following herbaria, who searched for and made available specimens: HBG, JE, LE, MICH, PAD, PC, S, TAA, UPS and ZT.

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MYCOTAXON

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PULVINULA BOUD., A SYNONYM FOR PULPARIA KARST.

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ABSTRACT

The holotype collection of Pulparia arctica Karst. 1866 has been studied and a re-evaluation of microscopic characters reveal this taxon to be congeneric with the younger genus Pulvinula Boud. 1885.

INTRODUCTION

Karsten (1866: 205) described the genus Pulparia with one species: Pulparia arctica Karst. (l.c.: 205-206). Pulparia arctica was mentioned later by Karsten, f.i. in 1868 (as Peziza arctica) and 1871 (as Pulparia arctica), but otherwise it was either forgotten or "long a doubtful one" (Korf, 1972: 978) until Korf et al. (in Korf, 1971) emended the genus after having studied the holotype material. Rogers, Pfister and Korf found this material to be congeneric with the much younger genus Marcelleina Brumm., Korf and Rifai (in Brummelen, 1967). They consequently (in Korf, 1971) transferred three Marcelleina species to Pulparia, a disposition which was accepted by several contemporary authors.

DESCRIPTION AND DISCUSSION

The present author has also studied the holotype material of Pulparia arctica, together with one additional collection from the same locality. The holotype collection is well preserved and rather rich. Karstens description (l.c.), which is fairly detailed runs as follows:

P. arctica n.sp. - Cæspitosa; cupula primum clavæformis vel oblongata, tandem discoidea, applanata, marginata, subgelatinosa, cæsia, deorsum in stipitem brevem crassum protracta; asci clavato-cylindraci, longit.circit. 173 mm. (pars sporifera 80-84 mmm), crassit. 11-13 mmm.; paraphyses filiformes, gracilescentes, flexuosæ, longissimæ; sporæ sphæroideæ, uniseriales, hyalinæ, longit.et crassit. 10-11 mmm. Syn. Peziza umbonata Pers. p.p.

Ad lignum mucidum salicinum in salicetis umbrosis uliginosis haud procul a Kola versus Tuloma, die 27 Julii.

Macroscopically very little can be added to this description on the basis of the studies of the two collections mentioned above. The holotype is labelled "Herbarium Petter Adolf Karsten (1834-1937) No. 3001". The second collection bears No. 3002. Both collections are made on 27.vii.1861. Kola now belongs to Russia (68°58'N,33°20'W).

The apothecia are disc-shaped to low turbinate (Fig. 1a), 0.5-2 mm broad, margin inconspicuous or lacking, all over light brown.

From the holotype collection one apothecium was soaked in water overnight and cut into two portions. One half was fixed and sectioned according to the method described by Dissing and Sivertsen (1988). Details of asci, paraphyses and spores were studied from the second half where the water afterwards was substituted by Cotton Blue (Figs 1 c-e).

The outer excipulum (Fig. 1b) is made up of angular cells; medullary excipulum of densely interwoven hyphae-like cells. Asci 180-200 x 10-11.5 µm, with deeply forked base (Fig. 1c). The spores are 10.0-10.8-11.2 µm, perfectly globose, smooth, uniseriate (Fig. 1d). Paraphyses hooked to circinate, 1-1.7 µm broad, below often branched and anastomosing (Fig. 1e).

All characters pictured in Figs 1c-e point to a species of the genus *Pulvinula* rather than a species congeneric with any *Marcelleina*. This has already been accepted by some authors (cf. Pfister 1985 and Moravec 1987).

For nomenclatorial reasons it would be very unfortunate for *Pulparia* to replace *Pulvinula*. This problem is treated in a separate paper where it is proposed to conserve *Pulvinula* over *Pulparia*.

Finally it should be mentioned that even if it becomes widely accepted that *Pulparia arctica* is a *Pulvinula*, no other *Pulvinula* species is known with a light bluish colour (cæsia = greyish or bluish) nor is any other species of this genus known to be wood-inhabiting.

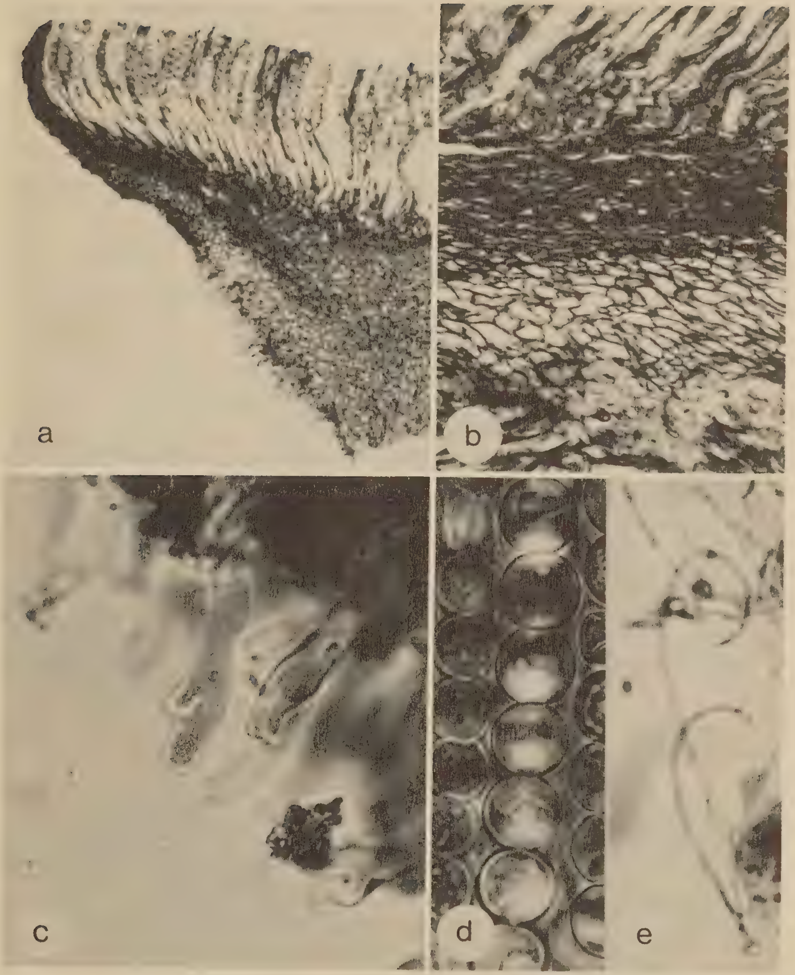

Fig. 1. Pulparia arctica, holotype. a & b. Ultramicrotome sections, 2 µm thick, method according to Dissing & Sivertsen, 1988. a. Survey of apothecium. b. Details of outer excipulum, and medullary excipulum supporting the hymenium. c. Distinctly forked bases of asci, in Cotton Blue. d. Perfectly uniseriate, globose, ascospores, in H_2O. e. Circinate, branched paraphyses, in Cotton Blue. a. x 113.75, b. x 455, c. x 1085, d. x 1085, e. x 455.

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Dr. H. Harmaja kindly arranged the loan of *Pulparia arctica* from the Botanical Museum, Helsinki. S. Sivertsen, Trondheim made valuable suggestions during preparation of the paper. Ruth B. Jakobsen made the sections and photos. Anne-Grete Kreiborg typed the manuscript. Their co-operation is greatly appreciated.

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MYCOTAXON

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A GREENISH GREY SPECIES OF SYMPODIOPHORA ARNOLD (HYPHOMYCETES)

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ABSTRACT

Sympodiophora viridigrisea Arnold, Illman and White, a new anamorph collected on a basidiome of Phellinus punctatus (Fr.) Pil. is described and compared with other species of the genus.

INTRODUCTION

The genus Sympodiophora Arnold (1970) based upon S. stereicola growing on the host fungus, is characterized by conidiogenous cells which proliferate in regular sympodially fashion in contrast to the irregular disposition of conidiogenous loci in the genus Pseudohansfordia described a few months earlier by Arnold (1969). De Hoog (1978), on the basis of similarity of axenic cultures, believed them not to warrant separate generic ranking. Deighton and Pirozynski (1972) described four new species of Sympodiophora and transferred an additional three from the genera Eriomycopsis, Dactylaria and Acremonium. Carey and Rogerson (1981) described the anamorph of Hypomyces polyporinus as Sympodiophora polyporicola, and provided a key to the known species of Sympodiophora. Matsushima (1981) added another species described as Pseudohansfordia ponapensis sp. nov. All of these are described as forming whitish colonies,

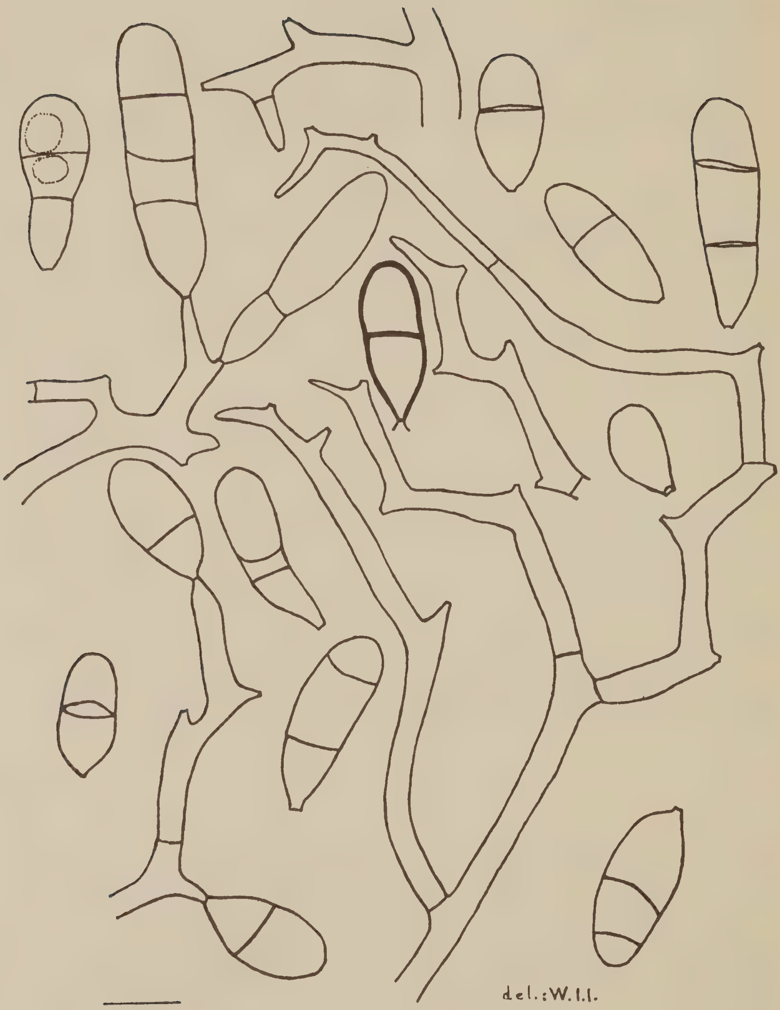

Fig. 1. Sympodiophora viridigrisea, conidiophore tips and conidia; (from type). line = 10 µm.

except for *S. didyma* which is pale yellowish green color when very dense; whitish when less dense. In contrast, a collection by G. P. White on the basidiome of *Phellinus punctatus* (Fr.) Pilát demonstrates a dense felt, colored greenish gray (Munsell value 4.5/) by prolific production of distinctly pigmented conidia. It apparently warrants description as *Sympodiophora viridigrisea sp. nov.*; its mode of conidiogenesis appears to match that of the type of the genus, *S. stereicola*, as illustrated by Cole and Samson (1979). Latin color names follow Dade (1943) and English names Kelly and Judd (1955). These names are supplemented by Munsell (1942) notations.

Sympodiophora viridigrisea G.R.W.Arnold, G.P. White, et W.I. Illman, sp. nov.

Colonia in substrato naturali effusa, superficialis, subiculosa, primum sordida alba demum virdigrisea. Hyphae ramosae, septatae, hyalinae, 2.5-6.8 µm crassae.

Conidiophora ramosa, intricata, 4-8 µm diam., septata, hyalina, in extremitates conidia generant.

Conidia acrogena apice cellularum sporogenarum et denticulorum oriunda, cylindrica vel obovata vel obpyriforma, sicca, levia, 1-2(-3) septata, colorata prime subvirida (5G9/2.5) postea, in desiccatae, olivacea-bubalina (5Y8/3) luce transmissa; hilo nitida praedita, 14-27x6-10 µm (Fig. 1; Plate 1).

Chlamydosporae in natura rarior sed in cultura agaro abundantes, luteae (10YR 7.5/12) luce transmissae, 10-18 µm crassae x 13-19 µm longae (Fig. 2). Holotypus: in basidiocarpo *Phellini punctati* (Fr.) Pil., Canada, Ontario, Temiskaming District, Tarzwell, 30.VIII.1979, G.P. White, DAOM 113666. Isotypi in JE; SYRF.

Sympodiophora viridigrisea sp. nov.

Colony upon the natural substrate subiculate, effuse, at first dingy white (5Y9/1) becoming at maturity, upon sporulation and drying, greenish to dark greenish gray (5G4.5/1). In axenic growth on PDA and 1.25% malt agar dried cultures show a central area of aerial mycelium of moderate yellow-brown (10YR4/4) color surrounded by submerged, darker, deep brown (2.5YR3/5) mycelium, the color of the reverse being dark brown (5YR2/3). The conidiophores, 4-8 µm in diameter, are profusely branched and intricately intertwined to produce a dense felt up to 1 mm or more deep. Their ultimate branchlets function as conidiogenous cells, and are at first simple and awl-like producing one or more conidia at the apex, then proliferating sympodially several times to form a geniculate and denticulate structure (Fig. 1; Plate 1) with successive conidiogenous loci.

Conidia acrogenous at tip of conidiogenous cell and later on denticles of geniculate structure, cylindric to obovate to obpyriform, dry, smooth, 1-2(-3) septate (Fig. 1; Plate 1) not usually constricted at septa, at first colored very pale green (5G9/2.5), later, upon drying, pale grayish yellow (5Y8/3) by transmitted light; base with a glistening hilum; 14-27(-35)x6-10 µm.

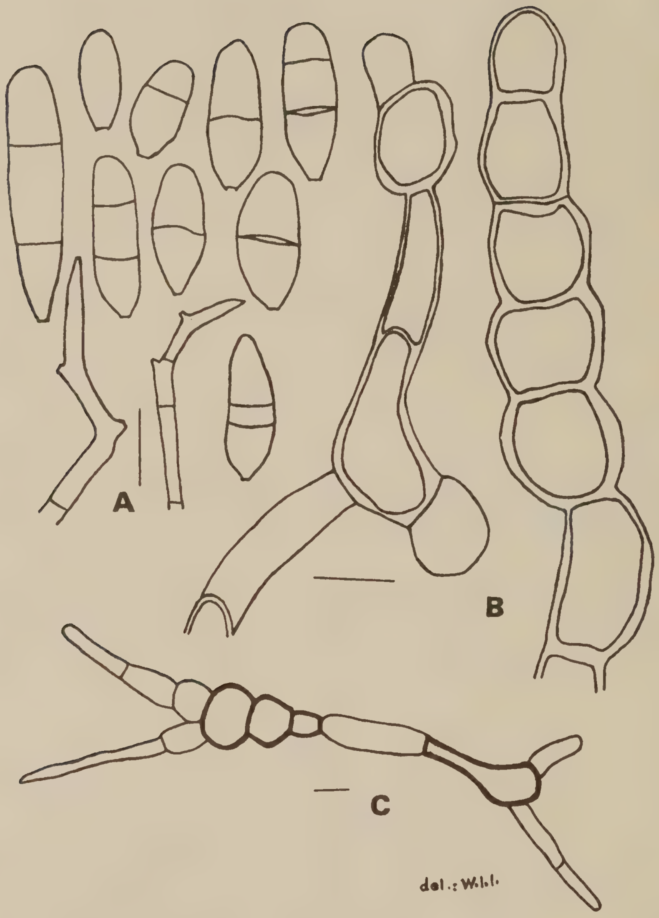

Fig. 2. Sympodiophora viridigrisea.

A. Conidiophore tips and conidia from re-growth on PDA of culture from type collection stored under mineral oil.

B. Chlamydospores from dried PDA culture on PDA made from type collection; camera lucida using oil immersion objective.

C. Chlamydospores from stored stock culture, germinated on fresh PDA medium; camera lucida, high dry objective. All lines represent 10 μm for their respective drawings.

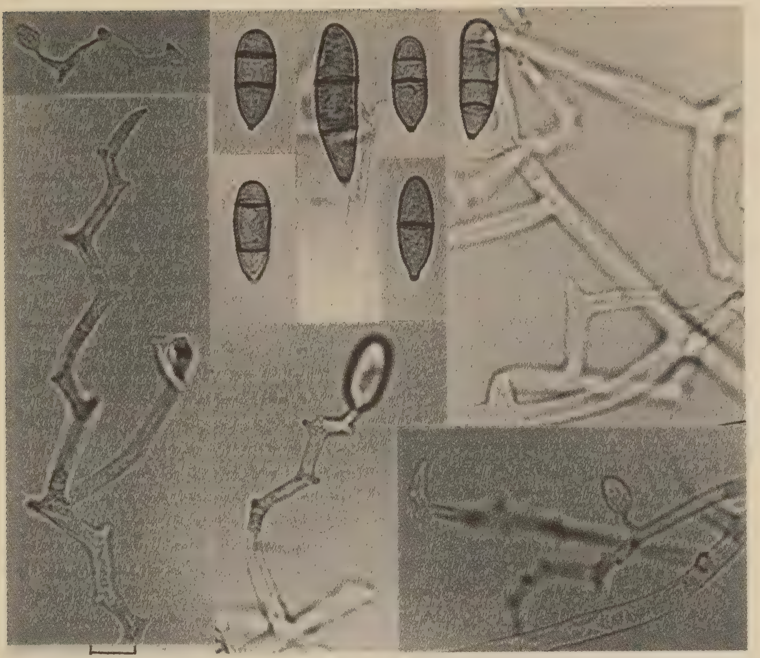

Plate 1. Sympodiophora viridigrisea, conidia and conidiophores photographed under high dry microscopy; scale = 10 µm.

Chlamydospores occasional on the natural host but abundant in axenic cultures on agar, produced singly or in short chains on side branches or in intercalary chains (Fig. 2), 10-18 µm diam. by 13-19 µm long, the walls up to 1.8 µm thick and strong orange-yellow (10YR7.5/12) in transmitted light.

This species notably differs from the type of the genus, S. stereicola Arnold, and also from described species, by producing distinctly colored conidia in abundance giving the mature colony a distinctive greenish gray aspect (value 4.5) and by the variable number of septa (1-3) in the conidia. Connection with a teleomorph is not established. Living and dried cultures are deposited in the culture collection of the BRC, Ottawa, Pilzkulturensammlung, Weimar and the College of Forestry, Syracuse, N.Y.

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MYXOMYCETES FROM ARKANSAS

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ABSTRACT

This first paper on the Myxomycetes of Arkansas includes 87 taxa, with one species, *Macbrideola declinata*, described as new to science. It is characterized by dichotomously branching capillitial threads that arise at the apex of the columella and then arch downward becoming attached to the peridium in the basal part of the sporangium. Approximately 40 of the listed species occur in corticolous habitats on living trees and vines, including the seldom collected *Clastoderma pachypus*, C. *microcarpum, Didymium synsporon, Echinostelium coelocephalum, Licea inconspicua, L. perexigua,* and *L. scyphoides.* Ground sites yielded *Reticularia jurana* (previously only known from Texas in the United States), *Didymium ovoideum* and *Calonema aureum.* Three species, possibly new to science, remain unnamed but are given brief descriptions and are illustrated.

INTRODUCTION

A search of the pertinent literature dealing with the Myxomycetes of North America, which includes the works of Macbride and Martin (1934), Hagelstein (1944), Martin (1949), and Martin and Alexopoulos (1969), reveals no species that has been reported in print as occurring from the state of Arkansas. An inventory of all slime mold specimens deposited in the University of Iowa Myxomycete Collection, Iowa City, Iowa, included no voucher specimens from Arkansas. Lack of published information on the myxomycetes of Arkansas is surprising. This state, because of its varied habitats and moderate temperatures, should be expected to have an interesting myxomycete biota.

Based on topography, geological conditions, and dominant vegetation types, Arkansas can be divided into two main regions: the Interior Highlands and the Gulf Coastal Plain (Arkansas National Area Plan, 1974). The Interior Highlands comprise the Ozark Mountains and the Oachita Mountains. The Ozark Mountains are made up of three plateaus in the northernmost part of the state with Upland Hardwood as the general vegetation type. The Oachita Mountains occupy the western central part of the state and display extensive folding and faulting; this mountain system is essentially a series of east-west-trending ridges with Shortleaf Pine *(Pinus echinata)* - Upland Hardwood as a general vegetation type. The Gulf Coastal Plain comprises the West Gulf Coastal Plain in the south with Loblolly Pine *(Pinus taeda)* as a general vegetation type, and the Mississippi Alluvial Plain with Bottomland Hardwood and Lowland Prairie as the general vegetation types. The latter is, apart from the Crowley's Ridge, primarily a delta land. Each of the subregions mentioned can be further subdivided into smaller sections with geological, topographical, and vegetational characteristics (Arkansas Natural Area Plan, 1974). Different ecological conditions and a wide range of different substrata offered by a varied flora of vascular plants create excellent conditions for a rich myxomycete biota. Extensive field work after favorable weather conditions is likely to result not only in a large number of species, but also in species new to science.

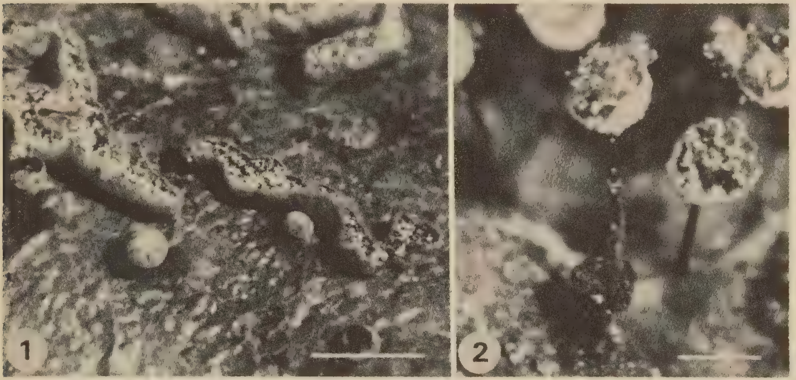
The present paper deals with 87 species of myxomycetes recorded to date from Arkansas. The true number of species is likely to be more than twice as large. This paper may encourage others to search productive habitats throughout Arkansas and will give interested persons a greater appreciation of the biotic diversity of this state. It also contains species of great taxonomic and ecological interest. One species is described as new to science. Three species probably new to science are illustrated and discussed without being formally described as new due to lack of ample material. Although myxomycetes in general are not likely to be a group of great ecological importance, when given the right conditions, some species may be locally very abundant and at least temporarily a conspicuous element in the field. Although the solution of many taxonomic problems will involve culturing under controlled conditions, extensive field work is needed to obtain material displaying the intraspecific variation of many poorly known species, and to provide more material for a better understanding of the biological diversity in this special group of organisms.

Myxomycetes of different species are often found close together, sometimes so intermixed that they cannot be separated without spoiling a large part of the material (Fig. 1). Occasionally sporangia of one species may develop on top of fructifications of a different species (Fig. 2). This means that parts of the plasmodium of one species crawled up on top of the sporangium of another species before fruiting.

Counties, localities within counties, collection dates, and kinds of substrata are cited where available. Collection dates are not given for moist chamber cultures, as the bark samples were sometimes taken long before the culture was started. We regard information on the substrata as important. Many species grow only on certain substrata; there also seems to be a difference between the myxomycete biota on living trees and that of fallen dead trees. Specimens are deposited in the herbaria of

Arkansas State University, Jonesboro, University of Arkansas at Fayetteville, and the National Fungus Collection in Beltsville, Maryland (BPI).

Nomenclature and order of species follow Martin and Alexopoulos (1969), except for *Badhamiopsis ainoae* (= *Badhamia ainoae* Yam.) and *Hemitrichia calyculata* (= *H. stipitata* (Massee) Macbr.). Abbreviations used: HWK = Harold W. Keller; JAH = James A. Hutchison; TEB = Travis E. Brooks; UHE = Uno H. Eliasson; MC = Moist Chamber collection.



Figures 1, 2. Fig. 1 *Physarum superbum* (plasmodiocarps) and *Didymium minus* (sporangia) on dead leaf (HWK 2688). Bar: ca. 1 mm. Fig. 2. *Didymium ovoideum* on top of sporangium of *D. minus* (HWK 2680). Bar: ca. 0.5 mm.

TAXONOMY

Ceratiomyxaceae

Ceratiomyxa fruticulosa (Müll.) Macbr.

Craighead Co.: Bayou de View, on well-decayed wood, November 1966, JAH 34. Stone Co.: Barkshed, on well-decayed wood, April 1967, HWK 1145. Washington Co.: Devil's Den State Park, on decaying log of *Ulmus*, 5 October 1987, UHE 3725.

Liceaceae

Licea biforis Morgan

Crawford Co.: 5 September 1964, TEB 2692. Craighead Co.: Jonesboro, on bark of *Catalpa speciosa* (MC), HWK 2717. Jonesboro, on *Vitis* sp. (MC), HWK 2716. Jonesboro, on bark from living *Tilia americana* (MC), HWK 1705.

Licea castanea G. Lister

Crawford Co.: On bark of living *Juniperus virginiana*, 7 February 1965, TEB 2678. Washington Co.: 7 February 1965, TEB 2784.

Licea chelonoides Nann.-Brem.

Crawford Co.: (MC) TEB 2701, (MC) 2759. 27 October 1964, TEB 2754.

Licea denudescens Keller & Brooks

Crawford Co.: (MC) TEB 2697. 5 September 1964, TEB 2674. 27 October 1964, TEB 2748, 2779. Logan Co.: 17 May 1964, TEB 2642. Sharpe Co.: Near Hardy, on moss-covered trunk of *Ulmus* sp. (MC), HWK 2000.

Licea inconspicua Brooks & Keller

Ashley Co.: *On Catalpa* sp. (MC), TEB 2670. Crawford Co.: On *Juniperus virginiana,* 27 October 1964, TEB 2756.

This is a distinctive species. Fructifications with an outer dark brown peridial layer may be strikingly different in color from those where the bright orange spore mass is surrounded by a thin membranous peridium. The large reddish orange spores with uniformly and minutely papillose ornamentation lack the thinner wall area seen in many species of *Licea*. This facilitates identification of the species.

Licea kleistobolus Martin

Craighead Co.: Jonesboro, on bark from living *Pinus taeda* (MC), HWK 1675. Jonesboro, on *Pinus taeda* (MC), HWK 2686, 2718. Crawford Co.: On bark of living *Juniperus virginiana,* 7 February 1965, TEB 2678. St. Francis Co.: 2 miles N of Forrest City, on bark from living *Taxodium distichum* (MC), HWK 1671, 1717.

Licea operculata (Wingate) Martin

Craighead Co.: Jonesboro, on bark from living *Vitis* sp. (MC), HWK 1670.

Licea parasitica (Zukal) Martin

Craighead Co.: Jonesboro, on bark from living *Tilia americana* (MC), HWK 1710, 1711. Jonesboro, on living *Ulmus parvifolia,* 30 July 1976, HWK 1895. Jonesboro, on bark of *Ulmus* (MC), HWK 2063. Crawford Co.: On bark of living *Juniperus virginiana*, 5 September 1964, TEB 2677 (intermixed with *L. pedicellata*). Mississippi Co.: Blythville, on bark from living *Ulmus parvifolia* (MC), HWK 1638.

Licea pedicellata (H.C. Gilbert) H.C. Gilbert

Crawford Co.: On bark of living *Juniperus virginiana,* 5 September 1964, TEB 2677; 27 October 1964, TEB 2744.

Licea perexigua Brooks & Keller

Crawford Co.: (MC) TEB 2700, 2759. On bark of *Juniperus virginiana*, 27 October 1964, TEB 2747, 2753. Logan Co.: (MC) TEB 2695.

Licea scyphoides Brooks & Keller

Mississippi Co.: Blythville, on bark from living *Juniperus virginiana* (MC), HWK 1672.

Licea sp.

Craighead Co.: Jonesboro, on *Juniperus virginiana* (MC), HWK 2719.

This species has a black spore mass and a minutely roughened spore surface with a sharply defined colorless area on one side. Specimens were identified by Nannenga-Bremekamp as *L. castanea*. Our concept of the latter species differs from the specimen cited most notably in the spore mass being pallid to brown with the spore surface smooth and the wall paler and thinner on one side.

Reticulariaceae

Dictydiaethalium plumbeum (Schum.) Rost.

Stone Co.: Blanchard Springs, on well-decayed wood, November 1986, JAH 80.

This is a true corticolous myxomycete but also occurs on decaying logs on ground sites. Forays in southwestern Ohio yielded numerous collections on the bark surface of living *Juniperus virginiana*, found along the trunk and extending up into the crown of the tree. Our forays into Arkansas were made under less than ideal conditions for corticolous myxomycetes. Under suitable weather conditions, this species will also probably be found abundantly on *J. virginiana* in Arkansas.

Lycogala epidendrum (L.) Fries

Carroll Co.: Holiday Island, on decaying wood, 8 October 1987, UHE 3747. Clay Co.: St. Francis Bayou, on decaying wood, May 1967, HWK 1157. Flood plain near St. Francis, on bark of decaying log, JAH 152. St. Francis Co.: Beatty Lake, Forrest City, on decaying wood, June 1968, HWK 1158. Stone Co.: Barkshed, on decaying wood, October 1967, HWK 1149. Blanchard, on well-decayed wood, November 1966, JAH 64. Washington Co.: Devil's Den State Park, on decaying wood, 5 October 1987, UHE 3706, 3724.

Lycogala exiguum Morgan

Washington Co.: Devil's Den State Park, on decaying log of *Ulmus*, 5 October 1987, UHE 3726.

Reticularia jurana Meylan

Clay Co.: St. Francis Bayou, on well-decayed wood, May 1967, HWK 1148. Stone Co.: Blanchard Springs, on well-decayed wood, November 1966, JAH 54. Washington Co.: Devil's Den State Park, on decaying wood, 5-6 October 1987, UHE 3707, 3735, 3743.

Although one of the pulvinate aethalia has a longest extension of more than 2 cm, most of the about 10 fructifications seen do not exceed 1 cm. The smaller size and the less robust capillitium distinguish this species from *R. splendens* Morgan. Both species have pulvinate brown aethalia and a conspicuous white hypothallus forming a white margin around the fructification. The basic structure of the pseudocapillitium is the same in the two species, although that of *R. splendens.* is more robust with a lesser tendency to be frayed into threads. Martin and Alexopoulos (1969) cite *R. jurana* only from Texas in the United States, whereas *R. splendens* is said to be very common in North America.

Cribrariaceae

Cribraria violacea Rex

Craighead Co.: Jonesboro, on bark from living *Juniperus virginiana* (MC), HWK 1719. Polk Co.: Near Lake Wilhelmina, on bark of *Quercus alba* (MC), UHE 3760.

Dictydium cancellatum (Batsch) Macbr.

Lee Co.: St. Francis National Forest, on well-decayed wood, March 1966, JAH 2. Washington Co.: Devil's Den State Park, on decaying wood, 5 October 1987, UHE 3723.

Echinosteliaceae

Echinostelium coelocephalum Brooks & Keller

Craighead Co.: Jonesboro, on bark of *Cercis canadensis,* 7 February 1974, HWK 1171. Crawford Co.: On bark from living *Juniperus virginiana* (MC), TEB 2688. Polk Co.: Queen Wilhelmina State Park, on bark of *Quercus alba* (MC), UHE 3769.

Echinostelium elachiston Alexop.

Crawford Co.: (MC) TEB 2764.

Echinostelium fragile Nann.-Brem.

Craighead Co.: Jonesboro, on bark from living *Liquidambar styraciflua* (MC), HWK 1169.

Echinostelium minutum deBary

Craighead Co.: Jonesboro, on bark from living *Vitis* sp. (MC), HWK 1793.

Echinostelium sp.

Carroll Co.: Holiday Island, on bark of *Quercus alba* (MC), UHE 3767. Craighead Co.: Jonesboro, on bark from living *Ulmus* (MC), HWK 2015. Polk Co.: Near Lake Wilhelmina, on bark of *Quercus alba* (MC), UHE 3770.

These sporangia were numerous in all collections. Total height of erect sporangia extended up to 350 µm with a pinkish spore mass. Spores disperse leaving a single, persistent, spore-like body 8 µm in diam. This spore-like body appears to be a columella and is subtended by a vase-like structure. Spores are 7-8 µm in diam with spore walls uniform in thickness and lacking ornamentation. This taxon resembles *E. apitectum* Whitney since both have spore-like columellae. However, in *E. apitectum* the spore-like body covers an elongate or conical columella, in contrast to the above taxon which lacks this kind of columella. Spores of these two taxa differ in size and surface markings. Sporangia of *E. apitectum* are much smaller in overall dimensions.

Dianemaceae

Calomyxa metallica (Berk.) Nieuwl.

Carroll Co.: Holiday Island, on bark surface of *Tilia americana* (MC), UHE 3768. Polk Co.: Queen Wilhelmina State Park, on bark of *Quercus alba* (MC), UHE 3761.

This species is common on the bark surface of living trees, especially species of *Juniperus*. When encountered in the field on living trees the fructifications are usually widely scattered and sporangiate. Many of the fructifications on UHE 3768 are plasmodiocarpous with abundant capillitium. The capillitial threads appear solid, marked with a surface ornamentation of minute papillae giving a roughened appearance.

Trichiaceae

Perichaena chrysosperma (Currey) A. Lister

Craighead Co.: Jonesboro, on decaying wood (MC), HWK 2685, 2686 (intermixed with *Macbrideola decapillata*). Jonesboro, on *Fraxinus pennsylvanica* (MC), HWK 2701. Lee Co.: St. Francis National Forest, on decaying wood, October 1966, JAH 22.

Perichaena depressa Libert

Craighead Co.: Bayou de View, on bark, November 1966, JAH 31.

Oligonema flavidum (Peck) Peck

Craighead Co.: Bayou de View, on decaying wood, November 1966, JAH 33. Washington Co.: On decaying wood, 1 January 1965, TEB 2734.

Oligonema schweinitzii (Berk.) Martin

Craighead Co.: Bayou de View, on well-decayed wood, November 1966, JAH 32. Lee Co.: St. Francis National Forest, on decayed wood, March 1966, JAH 5.

Calonema aureum Morgan

Washington Co.: On well-decayed wood, 1 January 1965, TEB 2726.

Arcyria cinerea (Bull.) Pers.

Craighead Co.: Craighead Park, on well-decayed wood, August 1967, JAH 10; October 1966, JAH 19. St. Francis Co.: Forrest City at Beatty Lake, on decayed wood, June 1968, HWK 1147. All collections represent the digitate form.

Arcyria denudata (L.) Wettst.

Carroll Co.: Holiday Island, on decaying wood, 8 October 1987, UHE 3759. Clay Co.: St. Francis Bayou, on well-decayed wood, May 1967, HWK 1156. Lee Co.: St. Francis National Forest, on decaying wood, October 1966, JAH 20.

Arcyria incarnata (Pers.) Pers.

Phillips Co.: Helena, on decaying wood, 1 April 1967, JAH 82, 88. Washington Co.: Devil's Den State Park, on decaying log of *Ulmus,* 5 October 1987, UHE 3727.

Arcyria magna Rex

Washington Co.: On bark, 20 December 1964, TEB 2722.

Arcyria nutans (Bull.) Grev.

Washington Co.: Devil's Den State Park, on decaying log, 5 October 1987, UHE 3718.

Metatrichia vesparium (Batsch) Nann.-Brem.

Carroll Co.: Holiday Island, on bark of decaying log, 8 October 1987, UHE 3746, 3749. Clay Co.: St. Francis Bayou, on decaying wood, May 1967, HWK 1157. Lee Co.: St. Francis National Forest, on decaying wood, October 1966, JAH 26; March 1966, JAH 7. Little River Co.: Near Cross Roads, on decaying wood, 4 October 1987, UHE 3702. Phillips Co.: Helena, on well-decayed wood, 1 April 1967, JAH 90. Sevier Co.: Along Highway 41, near border of Little River Co., on decaying stump, 4 October 1987, UHE 3703 (intermixed with *Trichia favoginea*), 3704. Washington Co.: On decaying wood, 1 January 1965, TEB 2729. Devil's Den State Park, on decaying log, 5 October 1987, UHE 3714, 3741.

Hemitrichia calyculata (Speg.) Farr

Carroll Co.: Holiday Island, on strongly decayed wood, 8 October 1987, UHE 3754. Craighead Co.: Jonesboro, on well-decayed wood, HWK 1151. Lee Co.: St. Francis National Forest, on well-decayed wood, March 1966, JAH 4; October 1966, JAH 19, 24. Washington Co.: Devil's Den State Park, on decaying wood, 5 October 1987, UHE 3710, 3733. Devil's Den State Park, on decaying log, 6 October 1987, UHE 3738 (intermixed with *H. clavata* and *Comatricha typhoides*).

Hemitrichia clavata (Pers.) Rost.

Carroll Co.: Holiday Island, on strongly decayed wood, 8 October 1987, UHE 3753, 3756. Washington Co.: On decaying wood, 1 January 1965, TEB 2727, 2733. Devil's Den State Park, on decaying log, 6 October 1987, UHE 3736, 3737. Devil's Den State Park, on decaying log, 6 October 1987, UHE 3738 (intermixed with *H. calyculata* and *Comatricha typhoides*).

There is generally a difference in habit between *H. calyculata* and *H. clavata* in so far as the former species has a distinct stipe whereas the sporangia of the latter species gradually narrow into the stipe. The capillitium of *H. clavata* is normally rougher than that of *H. calyculata* with more distinct and more numerous spinules. The spores of *H. clavata* are often faintly reticulate whereas those of *H. calyculata* are normally punctate. Although the two species in most cases appear distinct, differences are quantitative rather than qualitative, and a single fructification may display characteristics normally ascribed to different species. Both species may be found in close association on decaying wood.

Hemitrichia serpula (Scop.) Rost.

Carroll Co.: Holiday Island, on decaying wood, 8 October 1987, UHE 3745. Stone Co.: Barkshed, on well-decayed wood, October 1967, HWK 1146.

Trichia contorta (Ditmar) Rost.

Crawford Co.: Love Cemetery, on bark of living *Juniperus virginiana*, 27 October 1964, TEB 2746, 2749.

Trichia favoginea (Batsch) Pers.

Little River Co.: Along Highway 8, near Cross Roads, on decayed wood, 4 October 1987, UHE 3700. Phillips Co.: Helena, on well-decayed wood, 1 April 1967, JAH 87. Sevier Co.: Along Highway 41 near border of Little River Co., on decaying stump, 4 October 1987, UHE 3703 (intermixed with *Metatrichia vesparium*). Washington Co.: On decaying wood, 1 January 1965, TEB 2730, 2732. Devil's Den State Park, on decaying wood, 5 October 1987, UHE 3708, 3713, 3717.

Trichia varia (Pers.) Pers.

Carroll Co.: Holiday Island, on decaying log, 8 October 1987, UHE 3750, 3752. Craighead Co.: Bayou de View, on bark, November 1966, JAH 30. Washington Co.: On decaying wood, 1 January 1965, TEB 2731. Devil's Den State Park, on decaying wood, 5 October 1987, UHE 3728-3732.

Stemonitaceae

Enerthenema papillatum (Pers.) Rost.

Sevier Co.: Along Highway 41, near border of Little River Co., on bark of *Taxodium distichum* (MC), UHE 3764.

This taxon was found in Ohio on living bald cypress trees *(Taxodium distichum)* (HWK 1227, 1228), on white cedar *(Thuja occidentalis)* (HWK 1179), and on grapevine (HWK 1101). Abundant fruitings were collected in the field in situ. It is interesting to note that the late Dr. Travis E. Brooks did not list this taxon in his study of corticolous myxomycetes (1967). Martin and Alexopoulos (1969) describe this species as having "capillitium depending from the apical disk, the threads long, dark, flexuous, sparsely branched." In the material where a cupulate apical disk is conspicuously present some of the capillitial threads arise from this point. However, capillitial threads also arise throughout the length of the columella. Spore size (10-12 µm), ornamentation, and color agree with previous monographers' descriptions. Capillitial threads arising from the apical disk follow the horizontal contour of the upper surface of the sporangium, unlike in some specimens where the capillitial threads are oriented downward. The specimens cited above in some cases lack an apical disk and capillitial threads arise only from the columella. Further study is needed to determine the taxonomic status of collections from ground sites and living trees.

Stemonitis axifera (Bull.) Macbr.

Clay Co.: Flood Plain near St. Francis, on bark of decaying log, May 1967, JAH 150. St. Francis Bayou, March 1967, on decaying log, March 1967, HWK 1153. Washington Co.: On decaying log, 1 January 1965, TEB 2728.

Stemonitis fusca Roth

Carroll Co.: Holiday Island, on decaying log, 8 October 1987, UHE 3744. Craighead Co.: Wiener, on decaying log, June 1968, HWK 1154. Lee Co.: St. Francis National Forest, on decaying wood, October 1966, JAH 21, 29.

Stemonitis hyperopta Meylan

Stone Co.: Blanchard Springs, on decaying wood, May 1966, JAH 10.

Stemonitis pallida Wingate

Washington Co.: Devil's Den State Park, on decaying wood, 5 October 1987, UHE 3709.

Stemonitis smithii Macbr.

Carroll Co.: Holiday Island on Tablerock Lake, on oak leaf litter, 21 June 1986, HWK 2427. Holiday Island, on decaying wood, 8 October 1987, UHE 3751, 3758.

Clastoderma microcarpum (Meylan) Kowalski

Crawford Co.: On bark from living *Juniperus virginiana* (MC), TEB 2682. Sharpe Co.: Near Hardy, on living *Ulmus* sp., 31 July 1976, HWK 1897. Near Hardy, on moss-covered bark of *Ulmus* sp. (MC), HWK 2006.

Clastoderma pachypus Nann.-Brem.

Crawford Co.: On bark from living *Juniperus virginiana* (MC), TEB 2698.

Macbrideola cornea (G. Lister & Cran.) Alexop.

Crawford Co.: On bark of *Juniperus virginiana* (MC), TEB 2699.

Collections of this species from other states were frequently made by HWK on the bark surface of living trees, especially species of *Juniperus*.

Macbrideola decapillata H.C. Gilbert

Craighead Co.: Jonesboro, on decaying wood (MC), HWK 2685, 2687 (intermixed with *Perichaena chrysosperma*). Logan Co.: (MC) TEB 2671. On bark from living *Juniperus virginiana* (MC), TEB 2693.

Macbrideola declinata Brooks & Keller, **sp. nov.** Figs. 6-8,13-16.

Sporangia sparsa, stipitata, globosa, nitida vel rugulosa, argentea vel aenea vel aurea vel atropurpureo-brunnea, frequenter aliquantum iridescentia, 0.1-0.2 mm diam, 0.2-0.35 mm altitudine tota; peridium membranaceum, translucidum vel aliquatenus opacum, aliquantisper remanens, ad basim sporangii tamquam annulum reliquens; stipes erectus, subulatus vel cylindricus, atratus vel atroruber, cum hypothallo exiguo rotundo rubeo continuus, 80-180 μm altitudine; columella pulla, ad medium sporangii attingens, ad apicem in 2-4 ramos primigenos divisa; capillitium abundans, laxum, e filamentis purpureo-brunneis, indivisis vel disperse dichotome divisis ramis alternis, generaliter gradatim declinatis compositum; sporae in cumulo brunneae, globosae, impariter verrucosae, 7-8 μm diam. Plasmodium album.

Holotypus: T.E. Brooks 2687 (BPI).

Sporangia (Figs. 6,13) solitary to scattered, globose, usually smooth, silvery, bronze, or gold-colored to dark purplish brown, rarely rugulose, especially when prematurely dried, frequently with metallic reflections and somewhat iridescent, 0.1-0.2 mm diam, 0.2-0.35 mm in total height; peridium membranous, persistent, marked on the inner surface with dark papillae, the basal portion persisting as a small collar (Figs. 7,8,14); stipe erect, subulate or cylindrical from an expanded base, hollow, pale at the base, becoming progressively darker red, the upper portion nearly black, 80-180 µm in height; columella dark, opaque, about 1/2 to 2/3 the height of the fructification, giving rise at the apex to 2-4 primary capillitial branches (Figs. 7,8,14); capillitium moderately abundant, lax, consisting of purplish brown threads extending at more or less right angles to the columella when short, or when longer tending to arch and deflex towards the base of the sporangium, simple or once to several times dichotomously divided, not attenuating at the extremities, the tips of the threads frequently attached to the peridium, with peridial fragments often adhering after dehiscence; spores (Figs. 15,16) brown in mass, pale violaceous by transmitted light, globose, distinctly and unevenly echinulate, 7-8 µm in diam. Plasmodium white, each apparently giving rise to a single sporangium.

Etymology: From the Latin *declinatus*, meaning bent or curved downwards, in reference to the arched capillitial threads.

Habitat: All of the collections cited below were obtained from living *J. virginiana* with the exception of UHE 3762.

Collections examined: Arkansas: Crawford Co.; (MC) TEB 2679, 2684, 2687 Holotype, 2763. 5 September 1964, TEB 2673. Polk Co.; Queen Wilhelmina State Park, on bark of *Quercus alba* (MC), UHE 3762. Kentucky: Cumberland Co.; 8 August 1965, TEB 2886, 26 August 1966, TEB 3046. Ohio: Adams Co; Serpent Burial Mound (MC), HWK 1345, 2287. Tennessee: Picket Co.; 20 August 1966, TEB 3007.

Macbrideola declinata is a corticolous myxomycete restricted to living trees, primarily *J. virginiana*. There is ample material available from 11 collections over a widespread area of Arkansas, Kentucky, Ohio, and Tennessee on which we base this species description. Paratypes of this species have been sent to NYBG, K, and GB.

This species most closely resembles *Macbrideola scintillans*. Differences in the two species can be summarized as follows: the overall size dimensions of sporangia are larger in *M. declinata* although the size range overlaps in the two species; in *M. declinata* the inner peridial surface is noticeably roughened as seen with the light microscope whereas in *M. scintillans* it appears smooth; in *M. declinata* the capillitial threads arise at the apex of the columella branching several times and arching downward (Figs. 7,8,14), becoming firmly attached to the lower portion of the peridium, whereas in *M. scintillans* the capillitial threads are strongly attached to the upper portion of the peridium (Fig. 4), never undergoing any further branching. Collectively these characteristics easily separate these two species. No specimens were seen that suggest a series of intermediate peridial and capillitial characters in these two species.

Recently Nannenga-Bremekamp and Yamamoto (1983) described *Macbrideola verrucosa* based on two sporangia preserved as slide mounts. Apparently only a single specimen exists even though two numbers are cited; the collector's number Yamamoto 1286 and a second number assigned as NENB 12,909 to the same specimen. No information is given concerning the location of the holotype.

The specific epithet *verrucosa* refers to the prominently warted peridium, a character also exhibited by *M. declinata*. Overall size dimensions of *M. verrucosa* fall within the range of *M. declinata* and *M. scintillans*. The capillitium of *M. verrucosa* is described as "absent or scanty, just a few, thick, short branches (about 3-15 µm long) connected to the apex of the columella". One of us (HWK) has often observed that capillitial systems can be extremely variable, sometimes becoming suppressed by premature drying.

The capillitium of *M. declinata* differs from that of all other species of *Macbrideola* in the extensive dichotomously branching threads arched downward and becoming firmly attached to the peridium in the basal portions of the sporangium.

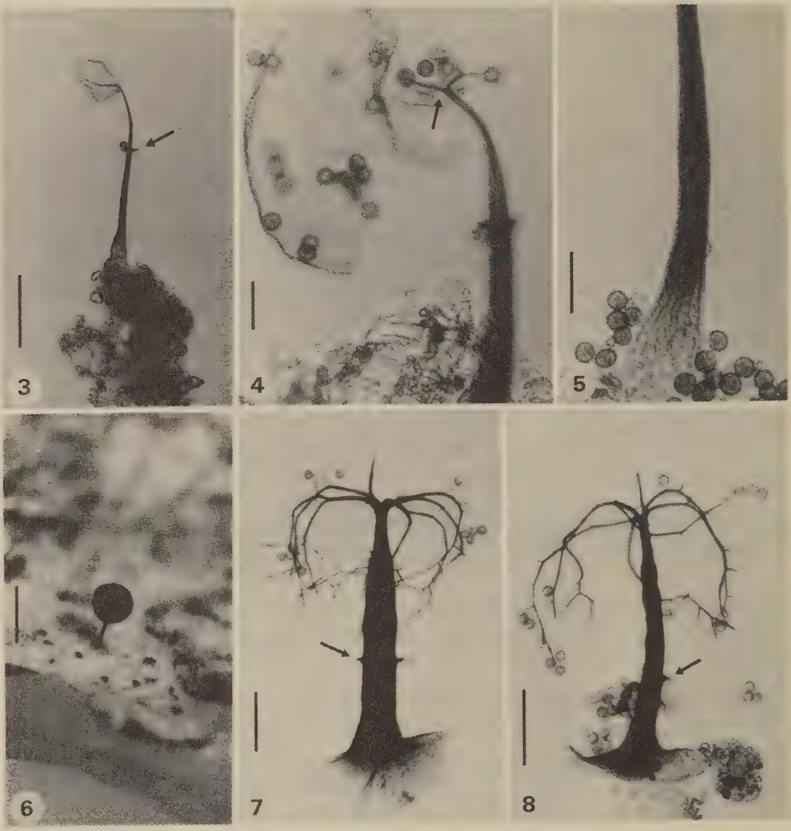
Macbrideola scintillans H.C. Gilbert Figs. 3-5, 9-12.

Carroll Co.: Holiday Island, on bark from living *Quercus alba* (MC), UHE 3763.
Lawrence Co.: Near Black Rock, on bark from living *J. virginiana* (MC), HWK 2040.

This species appears morphologically most similar to *Macbrideola declinata*. Abundant sporangia developed in moist chamber cultures served as the basis for a more complete species description.

Sporangia (Fig. 9) scattered, stipitate, 125-300 µm in total height, 50- 150 µm in diam, globose, metallic bronze or silvery; stalk hollow, yellow and broader at base (Fig. 5), tapering and translucent reddish brown above, 50-200 µm in height, continuing into the sporangium as a columella 60-90 µm in length (Fig. 10); peridium thin, the outer surface shiny (Fig. 9) (like tin foil), the inner surface smooth, persistent and often clinging to the tip of the columella, leaving a collar at the juncture of the stipe (Figs. 3,10); columella tapering and usually forking at the apex (Fig. 4) into one or two branches firmly attached to the peridium by their tips (Figs. 3,4); capillitium scanty, consisting of only the apical branches arising at or near the apex of the columella; spores (Figs. 11,12) globose, 8-11 µm, dull brown in mass, regularly spinulose.

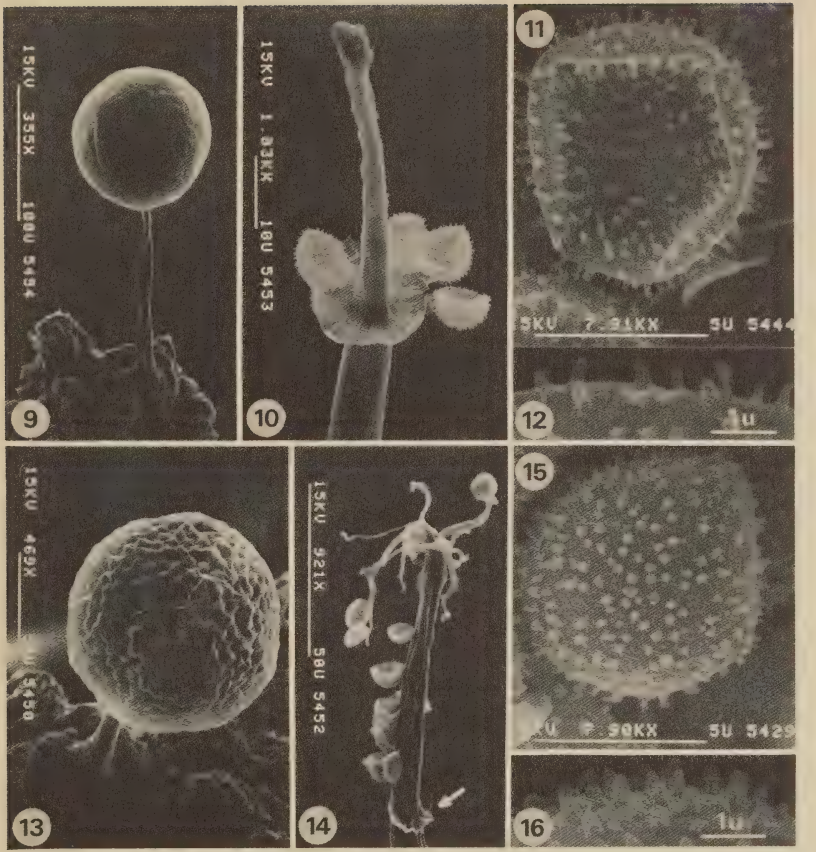
This description differs in several respects from previous published descriptions. The inner peridial surface is smooth without any kind of ornamentation as seen with the oil (100x) phase objective. The peridium remains firmly attached at the apex making it difficult to pull free with dissecting needles. Spore ornamentation is more conspicuous than in many species of *Macbrideola* and appears spinulose in optical section.



Figures 3-8. *Macbrideola scintillans* (Figs. 3-5; UHE 3763) and *M. declinata* (Figs. 6-8; UHE 3762). Fig. 3. Emptied sporangium with peridial collar (arrow) and peridium persisting at top of sporangium. Bar: 100 µm. Fig. 4 Top of dehisced sporangium with peridium attached to tips of the branched (arrow) columella. Bar: 30 µm. Fig. 5. Lower part of stipe showing hollow translucent base. Bar: 30 µm. Fig. 6. Habit of sporangium. Bar: ca. 0.2 mm. Figs. 7, 8. Emptied sporangia showing lax downwardly arching capillitial branches. Note peridial collar (arrow). Bars: ca. 50 µm.

Lamproderma biasperosporum Kowalski

Craighead Co.: Jonesboro, on bark from *Diospyros* sp. (MC), JAH 857. Locality unknown: On bark from *Diospyros* sp. (MC), HWK 2721.


11
15KU 355X 100U 5494
15KU 1.03KX 10U 5453
9
10
12
1u
15
15KU 469X
13
14
16
1u
15KU 921X 50U 5452
5U 5444
5U 5429

Figures 9-16. SEMs of *Macbrideola scintillans* (Figs. 9-12; UHE 3763) and *M. declinata* (Figs. 13-16; HWK 2287, Ohio.) Fig. 9. Sporangium with smooth peridium. Fig. 10. Emptied sporangium with collapsed spores adhering to the peridial collar. Fig. 11. Collapsed spore. Fig. 12. Spore ornamentation. Fig. 13. Sporangium with wrinkled peridium. Fig. 14. Dehisced sporangium with reflexed capillitial branches and narrow peridial collar at base (arrow). Fig. 15. Spore. Fig. 16. Spore ornamentation.

Comatricha fimbriata G. Lister & Cran.

St. Francis Co.: 10 miles SW of Forrest City, on bark from living *Taxodium distichum* (MC), HWK 1677.

Comatricha typhoides (Bull.) Rost.

Clay Co.: St. Francis Bayou, on well-decayed wood, July 1967, JAH 23. Lee Co.: St. Francis National Forest, on decaying wood, October 1966, JAH 27.

Comatricha sp. A. Figs. 22, 23.

Carroll Co.: Holiday Island, on bark from living *Quercus alba* (MC), UHE 3766.

This collection consists of only two sporangia mounted on slides. The paucity of material makes it difficult to assign a name with any degree of confidence; the species appears to be undescribed and identical with the one discussed and illustrated by Nannenga-Bremekamp and Yamamoto (1983, fig. 19) and cited by them as "*Macbrideola* sp.".

Our material is considered a species of *Comatricha* because the lower portion of the stalk appears to be opaque and probably not hollow. Stalks of specimens such as this one need to be sectioned to determine whether hyaline strands partition the interior. The overall dimensions of 450-550 μm (total height) x 300 μm (sporangium diam) are slightly smaller than the specimens discussed by Nannenga-Bremekamp and Yamamoto (700 μm x 350 μm). The Arkansas specimen has a columella that extends up to 2/3 the height of the sporangium (Fig. 22), dividing at the apex into 4-6 primary branches that again branch (Figs. 22,23) dichotomously into a loose network united at the periphery into a partial surface net. Capillitial threads arise from all sides and throughout the length of the columella. The spores are minutely and uniformly spinulose and 10-11 μm in diam. Additional collections are needed to determine the taxonomic status of this taxon, especially because of the large number of species described in recent years in the genera *Comatricha* and *Macbrideola*.

Comatricha sp. B. Figs. 17-21.

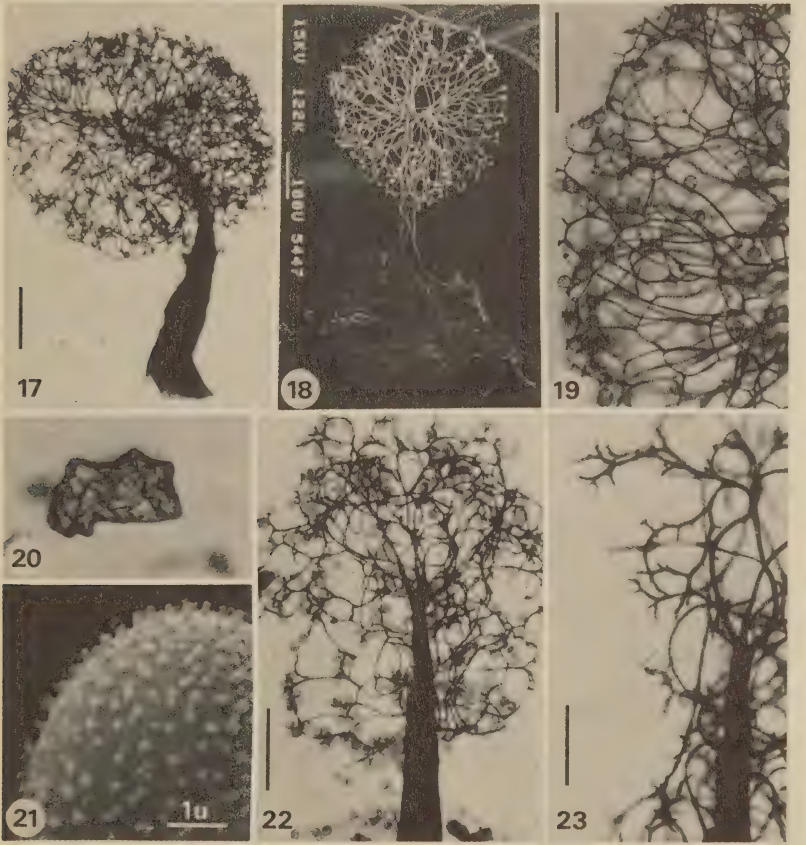
Crawford Co.: On bark of living *Juniperus virginiana*, 27 October 1964, TEB 2742.

This taxon was given the name "*Macbrideola robusta*" by Dr. Brooks in his thesis dissertation (1967), but the name was never formally published. One of us (HWK) has numerous collections of this taxon on *J. virginiana* mostly from Ohio. The following brief description is provided.

Sporangia scattered, stalked, dark reddish brown, 0.2-0.5 mm in diam, 0.3-0.7 mm in total height; peridium not apparent; stalk dark reddish brown, collapsing laterally to become irregularly fluted, translucent red by transmitted light, extending as a columella (Fig. 17) 1/3 to 1/2 the sporangial diameter; capillitium abundant, originating at or near the apex of the columella as a lax system of pale reddish brown threads which branch and anastomose to form a close meshwork of threads with many free ends (Figs. 18,19); spores dark reddish brown in mass, globose, minutely warted (Fig.21) with patches of darker warts in scattered clusters, 8-10 μm in diam.

Stalks of this taxon give the outward appearance of a *Macbrideola* species. Air bubbles were never seen trapped in the lumen of the stalk as is the case for many species of *Macbrideola*. Observation of the stalks with phase optics did not reveal any internal structure. Stalks embedded, sectioned, and stained with methylene blue clearly showed a network of internal hyaline threads that partition the stalk (Fig. 20). This taxon is a *Comatricha* if one separates *Macbrideola*, in part, on the basis of having a hollow stalk.

This taxon has only been found on the bark surface of living trees. It should be compared with specimens of *Comatricha laxa* Rost. and many species of *Comatricha* recently described by Nannenga-Bremekamp.



Figures 17-23. Two presumably undescribed species of *Comatricha* (Figs. 17-21, HWK 1284, Ohio; Figs. 22, 23, UHE 3766, Arkansas). Fig. 17. Sporangium in transmitted light. Bar: 100 µm. Fig. 18. SEM of sporangium. Fig. 19. Peripheral part of capillitium. Bar: 50 µm. Fig. 20. Stipe in cross-section. Internal hyaline threads partition stipe. Fig. 21. Spore ornamentation with truncate processes. Fig. 22. Sporangium in transmitted light. Columella divides at apex into 4-6 primary branches that rebranch. Bar: ca. 100 µm. Fig. 23. Peripheral part of capillitium. Bar: ca. 50 µm. — The species illustrated in Figs. 22 and 23 is identical with the one discussed and illustrated by Nannenga-Bremekamp and Yamamoto (1983) and cited by them as *"Macbrideola* sp.".

Physaraceae

Leocarpus fragilis (Dicks.) Rost.

Carroll Co.: Holiday Island on Tablerock Lake, on oak leaf litter, 21 June 1986, HWK 2430.

Badhamiopsis ainoae (Yama.) Brooks & Keller

Crawford Co.: On bark from living *Juniperus virginiana* (MC), TEB 2675, 2680, 2714, 2772.

This corticolous species is only known from living trees and occurs most frequently on species of *Juniperus* in the United States. Limeless specimens can be identified by the vertical orientation of the capillitial threads that bifurcate at the point of attachment at the base of the fructifications.

Badhamia affinis Rost.

Crawford Co.: On bark from living *Juniperus virginiana* (MC), TEB 2696. On bark of living *Juniperus virginiana*, 27 October 1964, TEB 2741, 2752.

Fruitings several feet in extension have been found on the bark of living trees, especially when moss-covered. Fruitings may occur all along the trunk, extending into the crown of the tree.

Badhamia armillata Nann.-Brem.

Crawford Co.: On bark from living trees (MC), TEB 2696, 2770. Logan Co.: On bark from living trees (MC), TEB 2773.

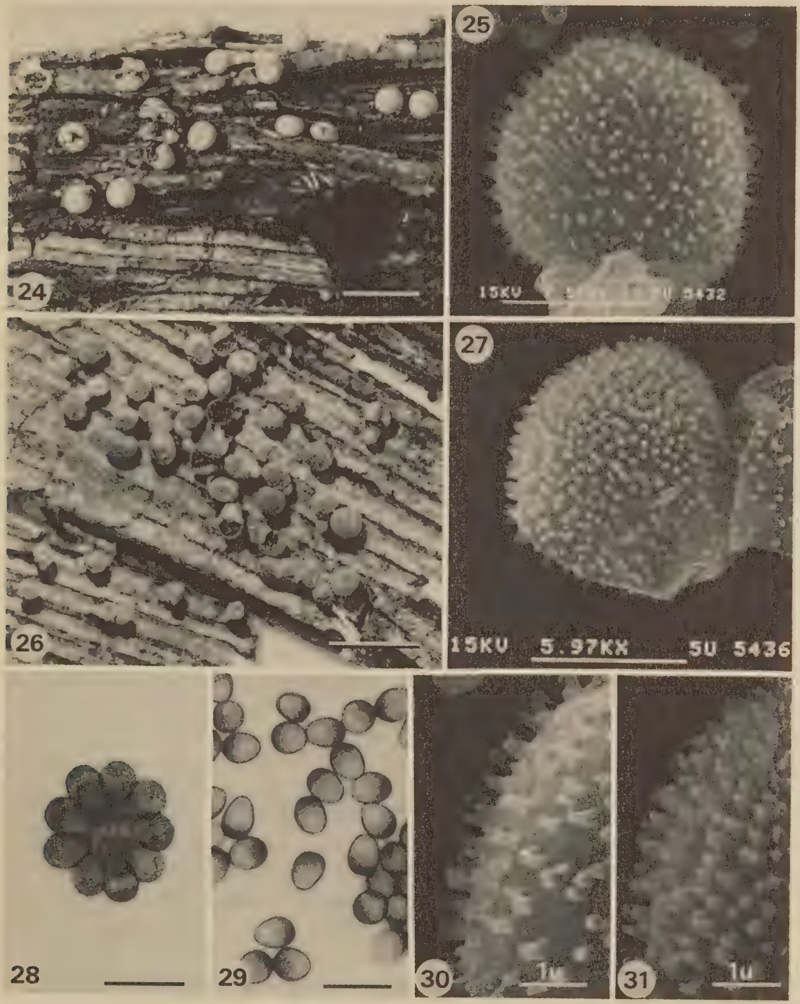
Badhamia gracilis (Macbr.) Macbr.

Craighead Co.: Jonesboro, on decaying bark on log, August 1969, HWK 1139.

Badhamia rugulosa Brooks & Keller Figs. 24,25,30.

Washington Co.: Devil's Den State Park, on bark of living *Vitis* sp., 5-6 October 1987, UHE 3719, 3721, 3740.

These ample fruitings covered extensive areas of the bark surface of grapevines occurring in close proximity. The sporangia show signs of weathering due to exposure to the elements for several weeks. Some sporangia were moldy, others had prematurely dried with agglutinated spore masses, still others appeared typical in every respect. Prematurely dried sporangia retain their bright orange color. Peridial coloration varies from bright orange to white in fructifications bleached after periods of long exposure. In properly matured sporangia the outer peridial layer flakes away. The peridium may be iridescent in forms with scanty lime. The capillitium is bright yellow, especially where still buried in the spore mass, and white where exposed to the elements. The spore mass is brown with powdery free spores.



Figures 24-31. *Badhamia rugulosa* (Figs. 24, 25, 30; UHE 3721) and a presumably undescribed species of *Badhamia* (Figs. 26-29, 31; UHE 3722) with clustered spores. Fig. 24. Sporangia on wood and bark of *Vitis* sp. Note plasmodial tracks in the foreground. Bar: ca. 2 mm. Fig. 25. Spore. Fig. 26. Sporangium on wood of *Vitis sp*. Bar: ca 2mm. Fig. 27. Spore. Fig. 28. Intact spore cluster in transmitted light. The inner faces of the individual spores adhere together around a central cavity. Bar: ca. 20 µm. Fig. 29. Spore cluster broken apart during slide preparation. Note darker (spiny) outer face and paler (smoother) inner face. Bar: ca. 20 µm. Figs. 30, 31. Spore ornamentation.

Badhamia versicolor Lister

Crawford Co.: On bark from living and dead trees (MC), TEB 2781, 2782.

Badhamia sp. Figs. 26-29, 31.

Washington Co.: Devil's Den State Park, on bark of living *Vitis* sp., 5 October 1987, UHE 3722.

Fructifications gregarious (Fig. 26), varying from short stipitate to sessile, globose sporangia 0.2 - 0.3 mm in diam, merging into plasmodiocarps 0.45 - 1.6 mm in length; peridium bright orange, bearing limy thickenings appearing as veins; capillitium consisting of strongly calcareous, bright orange tubules with few limeless threads; spore mass black, spores (Figs. 27, 29) ovate to pyriform, 10 - 12 x 10 - 14 μm, violaceous brown, adhering in compact, hollow clusters (Fig. 28) of 18 to 32, the inwardly directed spore surface smooth, the exposed surface minutely spinulose (Figs. 27, 31).

This collection was found on the same kind of substratum (but on a different grapevine specimen) as *B. rugulosa*. Based on general appearance these two taxa were initially confused, but the clustered-spored characteristic readily separates this taxon from *B. rugulosa*.

Fuligo cinerea (Schw.) Morgan

Craighead Co.: Jonesboro, on oak leaf litter, 24 May 1981, HWK 2703.

This is part of an extensive fruiting developed after a garden was fertilized with horse manure. The aethalia are very thin, mostly 1-2 mm, and up to 4 cm in longest extension. The cortex is bright white.

Fuligo septica (L.) Wiggers

Lee Co.: St. Francis National Forest, on decaying wood, October 1966, JAH 23.

Craterium leucocephalum (Pers.) Ditmar

Randolph Co.: On leaf litter, 16 October 1977, HWK 2702.

Physarum auriscalpium Cooke

Craighead Co.: Jonesboro, on bark of *Cercis canadensis* (MC), HWK 2722.

Physarum bivalve Pers.

Carroll Co.: Holiday Island on Tablerock Lake, on oak leaf litter, 21 June 1986, HWK 2428. Craighead Co.: Jonesboro, on living lawn grass, August 1967, HWK 1150. Jonesboro, on grass, June 1978, HWK 2704. Stone Co.: Barkshed, on decaying wood, April 1967, HWK 1153.

Physarum crateriforme Petch

Craighead Co.: Jonesboro, on bark from living *Juniperus virginiana* (MC), HWK 2629-2700, 2723, 2724. Jonesboro, on bark of living *Juniperus virginiana*, 30 July 1976, HWK 1893. Crawford Co.: On bark from living *Juniperus virginiana* (MC), TEB 2769, 2771, 2956. On bark of living *Juniperus virginiana*, 5 September 1964, TEB 2676; 27 October 1964, TEB 2745.

Whenever extensive lime deposits are present, the white peridium, the columnar columella reaching the sporangial apex, and the badhamoid capillitium, coupled with the cylindrical to obovate sporangial shape and black stalk, make this species easy to identify in the field. Occasionally, however, it can be troublesome to identify because of extreme variability in sporangial shape and degree of calcification. Some fruitings may be sessile and appear to lack lime anywhere in the fructification. In these cases the capillitium may consist of hyaline threads lacking lime knots and also a columella. The sporangia then often appear brownish in contrast to the typical white coloration. Unless typical sporangia are present it is impossible to identify these fruitings to species with certainty because the other possible identifying features, such as spore size and ornamentation, fall within the range of so many other species.

Sporangia may withstand the weather elements and survive for long periods of time on the bark surface of living trees. In these cases the peridial surface may undergo dramatic changes that lead to the reprecipitation of lime as plates, giving the surface a roughened appearance, or lime may be washed away, finally giving a brownish peridium with no evidence of lime on the sporangial surface. These sporangia are more difficult to see with the naked eye but nevertheless can be identified rather easily if the columella and capillitial system are present.

Fruitings of *P. crateriforme* usually occur as widely scattered sporangia or in small groups of usually less than six. This is quite unlike many other physaraceous species, such as, for example, *Badhamia affinis* and *Badhamia rugulosa*, which may extensively cover the bark surface with masses of fructifications. The fruiting habit of *P. crateriforme* suggests that on living trees the phaneroplasmodium remains rather small and probably either gives rise to one or a few sporangia. Attempts to culture this species on agar have failed.

This species has been recorded from ground sites such as dead wood or herbaceous stalks from the old world tropics (Lister, 1925). It is interesting to note that one of us (HWK) has never collected this species on ground sites in the United States. It occurs commonly throughout the central and southeastern United States and can probably be found wherever junipers, oaks, elms and grapevines are abundant and ample rainfall occurs between June and September.

This corticolous species is very common on living trees, especially on *Juniperus virginiana*. There it serves as an indicator species that easily can be seen with the naked eye because of its mostly white peridial coloration and relatively large size. When present on the trunks of trees, it indicates that there has been sufficient rainfall, so that other myxomycete species more difficult to see because of their smaller size, such as members of *Licea*, *Clastoderma*, and *Cribraria*, may also be present. Parts of the tree, such as crevices along the trunk surface, algal or mossy covered areas, the underside of lateral branches, or natural pathways where water flows down the tree, will usually yield additional fruitings of myxomycetes.

Physarum didermoides (Pers.) Rost.

Craighead Co.: Jonesboro, on decaying log and ground litter, August 1969, HWK 1140.

Physarum globuliferum (Bull.) Pers.

Carroll Co.: On decaying leaf litter, 8 October 1987, UHE 3748. Craighead Co.: Craighead Park, June 1968, HWK 1142. Wiener, June 1968, HWK 2726.

Physarum leucopus Link

Clay Co.: St. Francis Bayou, on leaf litter, May 1967, HWK 2693. Craighead Co.: Craighead Park, on decaying wood, June 1968, HWK 2691.

Physarum nutans Pers.

Sevier Co.: Along Highway 41, near border of Little River Co., on bark of *Taxodium distichum* (MC), UHE 3765.

Physarum polycephalum Schw.

Craighead Co.: Jonesboro, on *Zoysia* grass, 2 October 1981, HWK 2705.

Physarum roseum Berk. & Br.

Washington Co.: Devil's Den State Park, on mosses on decaying log, 5 October 1987, UHE 3712.

Physarum superbum Hagelst. Fig. 1.

Craighead Co.: Jonesboro, on decaying leaf litter, 30 July 1976, HWK 1886. Jonesboro, on decaying leaves, 3 August 1976, HWK 2688 (intermixed with *Didymium minus*; Fig. 1.).

Didymiaceae

Diderma chondrioderma (deBary & Rost.) G. Lister

Craighead Co.: Jonesboro, on bark of *Ulmus elata* (MC), HWK 1558, 2682. Jonesboro, on bark of *Cercis canadensis* (MC), HWK 2683, 2725. Crawford Co.: (MC) TEB 2765. Mississippi Co.: Blythville, on bark from living *Ulmus parvifolia* (MC), HWK 2684.

Diderma floriforme (Bull.) Pers.

Stone Co.: Blanchard Springs, on well-decayed wood, November 1966, JAH 75.

Mucilago crustacea Wiggers

Craighead Co.: Jonesboro, on decayed bark of log on ground, August 1966, HWK 1141.

Didymium megalosporum Berk. & Curt.

Carroll Co.: At Holiday Island on Tablerock Lake, on oak leaf litter, 21 June 1986, HWK 2531 (intermixed with *Leocarpus fragilis*); on leaf litter, 21 June 1986, HWK 2477 (intermixed with *Leocarpus fragilis* and *Didymium ovoideum*).

Didymium minus (A. Lister) Morgan Fig. 1.

Clay Co.: St. Francis Bayou, on decaying wood, May 1967, HWK 2689, 2692. Craighead Co.: Jonesboro, on decaying leaves, 30 July 1976, HWK 1889. Jonesboro, on leaf litter, 3 August 1976, HWK 2688 (intermixed with *Physarum superbum*).

Didymium ovoideum Nann.-Brem. Fig. 2.

Craighead Co.: Jonesboro, on decaying oak leaf litter, 30 July 1976, HWK 1886 (intermixed with *Physarum bivalve*), 1891, 1892. Jonesboro, on decaying leaf litter, 3 August 1976, HWK 2679, 2680 (intermixed with *Didymium minus*; Fig.2), 2708-2712. Cowles-Sylvan Hill Dr., on leaf litter, June 1979, HWK 2714, 2715; on dead *Pinus* needles on the ground, June 1979, HWK 2713.

Didymium synsporon Brooks & Keller

Crawford Co.: On bark of *Juniperus virginiana*, 27 October 1964, TEB 2743.

When this species was first described as new (Keller and Brooks, 1973), 15 collections were cited, all from the bark surface of living *Juniperus virginiana*. One of us has collected additional specimens of this species from Ohio (HWK 1332, 1458, 1459, 1460, 1466, 2143) and Georgia (HWK 2179), also from *J. virginiana* trees. *Didymium synsporon* usually forms widely scattered white fructifications that are difficult to see because they blend in with the light colored background of the bark.

It is apparent that *J. virginiana* supports a greater diversity of myxomycete species than other tree species, and is the only tree species where certain myxomycete species have ever been found. Apparently the roughened surface and fibrous bark texture serve to readily hold and absorb available moisture, thus providing a more optimal substratum for corticolous myxomycetes.

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We wish to thank Barry Hutchison for collecting specimens in the Jonesboro area. Some collections were made possible by Dr. E. Leon Richards. The late Dr. Travis E. Brooks placed all of his Arkansas specimens at our disposal. These specimens have been deposited at BPI. We wish to thank Jerry Helms and Joan Gilbreath for providing facilities and directions guiding us to various collecting sites at Holiday Island. Tim Scott, park naturalist at Devil's Den State Park, provided us with information about where to find certain trees and wet areas. Special thanks go to Jay Justice who supplied us with valuable information about collecting sites. Professor Åke Fridh kindly corrected the Latin diagnosis of *Macbrideola declinata.* This research was supported in part by grants BMS 75-19098 and DEB 75-19098A01 from the National Science Foundation and The University of Texas at Arlington Organized Research Fund to HWK. Early stages of this research were supported by ASU grant 511-628 to JAH. The Swedish National Science Research Council made possible the stay of UHE at The University of Texas at Arlington.

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NEW SPECIES IN THE LICHEN GENUS PARAPARMELIA (ASCOMYCOTINA) FROM THE SOUTHERN HEMISPHERE

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ABSTRACT : The species, *Paraparmelia aranaea* Elix & Johnston, *Paraparmelia ballingallii* Elix & Johnston, *Paraparmelia brownlieii* Elix & Johnston, *Paraparmelia columbariensis* Elix & Johnston, *Paraparmelia fumarprotocetrarica* Elix & Johnston, *Paraparmelia leucophaea* Elix & Johnston, *Paraparmelia neomongaensis* Elix & Johnston, *Paraparmelia norcapnodes* Elix & Johnston, *Paraparmelia poeltii* Nash, Elix & Johnston, *Paraparmelia roderickii* Elix & Johnston, *Paraparmelia sammyii* Elix & Johnston, *Paraparmelia sargentii* Elix & Johnston, *Paraparmelia sublineola* Elix & Johnston, *Paraparmelia subrugulosa* Elix & Johnston and *Paraparmelia tropica* Elix & Johnston are described as new. All the species, except the Venezuelan *P. poeltii*, occur in Australia.

Introduction

As a result of further study of the lichen genus *Paraparmelia* in the Southern Hemisphere, and particularly in Australasia (Brusse 1984, 1985, 1986a,b; Elix 1981; Elix & Johnston 1987; Elix, Johnston & Verdon 1986; Elix & Stevens 1979; Kurokawa 1985, Kurokawa & Filson 1975, Nash & Elix 1987), we are describing 15 new species. Throughout the present work chemical constituents were identified by thin layer chromatography (Culberson 1972; Culberson, Culberson & Johnson 1981; Culberson & Johnson 1982), high performance liquid chromatography (Lumbsch & Elix 1985) and comparison with authentic samples.

Paraparmelia aranaea Elix & Johnston, sp. nov. Figure 1

Species cum thallo ut in *Paraparmelia gregaria* sed ab hac specie lobis latioribus et acidum protocetraricum continente differt.

Type. Australia. Queensland. On rocks in *Eucalyptus* dominated grassland, Paluma Reservoir-Hidden Valley track, 34 km SSW of Ingham, 18°55'S, 146°05'E, 880 m, *J. A. Elix 20294 & H. Streimann*, 18.vi.1986; CBG-holotype.

Thallus small foliose, saxicolous, tightly adnate, pale grey to grey or darkening with age, to 5 cm in diameter; *lobes* irregular to sublinear-elongate, separate at the apices, ± contiguous within, barely imbricate, subdichotomously divided, 0.2-1.2 mm wide. *Upper surface* plane, shiny and black-margined towards the apices, becoming dull with age, emaculate, moderately isidiate, *isidia* globose to short-cylindrical, simple, often black-tipped, short, less than 0.2 mm high; medulla white. *Lower surface* black,

± with narrow brown marginal zone, moderately to sparsely rhizinate, rhizines simple, black. Apothecia and pycnidia not seen.
Chemistry: Cortex K+ yellow; medulla K+ pale yellow-brown, C-, P+ red-orange; containing atranorin, protocetraric acid.

This characteristic species resembles *Paraparmelia gregaria* Elix & Johnston in overall thallus morphology but the lobes are broader (0.2-1.2 mm wide), separate and radiating at the apices while those of *P. gregaria* are narrower (0.2-0.8 mm wide), contiguous and crowded. Furthermore *P. aranaea* produces medullary protocetraric acid (C-, P+ red-orange) while *P. gregaria* contains lecanoric acid (C+ red, P-). At present this species is known from several hinterland localities in north Queensland.

Specimens Examined
QUEENSLAND. Type locality, *J. A. Elix 20304 & H. Streimann*, 18.vi.1986 (ANUC); on granite rocks on edge of escarpment in *Eucalyptus-Casuarina* dominated woodland, Clarke Range, 46 km south of Proserpine, 20°50'S, 148°32'E, 800 m, *J. A. Elix 20915 & H. Streimann*, 29.vi.1986 (ANUC).

Paraparmelia ballingallii Elix & Johnston, sp. nov. Figure 2

Species cum thallo ut in *Paraparmelia prolata* sed ab hac specie thallo arcte adnato et acidum lobaricum continente differt.
Type. Australia. Queensland. Qmi. On rocks, rocky ridge in mulga scrub, Highlands Station, south of Emmet, west of Blackall, on road to springs, *c*. 6 km south of homestead, 25°00'S, 144°23'E, 300 m, *M. E. Ballingall 2282A*, 26.ix.1986; CBG-holotype.

Thallus foliose, saxicolous, tightly adnate, pale mineral grey, darkening to grey-black with age, to 5 cm in diameter; *lobes* irregular to sublinear, 1-3 mm wide, subrotund at the apices, contiguous or subascending at the margins, barely imbricate. *Upper surface* shiny and black-margined at the apices, then dull, emaculate, becoming tangentially cracked, markedly rugose and ± areolate with age, lacking isidia and soredia; medulla white. *Lower surface* smooth, shiny, pale tan but dark brown at the tips, moderately rhizinate, rhizines concolorous with the lower surface, simple or tufted at apices, short, *c*. 0.2-0.3 mm long, slender. *Apothecia* adnate to substipitate, concave at first then flattened or convex, to 3 mm in diameter, disc dark brown, becoming stellate-cracked, margin thin, involute at first, then incised, amphithecium smooth; spores (8), colourless, ellipsoid, 6-7 x 3.5-4 µm. Only pycnidia of a fungal parasite present.
Chemistry: Cortex K+ yellow; medulla K-, C-, KC-, P-; containing atranorin, lobaric acid, scabrosin 4,4'-diacetate, scabrosin 4-acetate 4'-butyrate, scabrosin 4,4'-dibutyrate, scabrosin 4-acetate 4'-hexanoate.

The pale lower surface, the medullary scabrosin derivatives and the lack of soredia and isidia immediately bring the South African species, *P. prolata* (Hale) Elix & Johnston, to mind. However the latter has linear-elongate, loosely adnate lobes and lacks medullary lobaric acid, whereas *P. ballingallii* has tightly adnate, sublinear to irregular lobes. Morphologically this new species resembles *P. spodochroa* (Kurok. & Filson) Elix & Johnston as both have similar, tightly adnate thalli with a pale lower surface and lack soredia and isidia. However the apical lobes are sublinear in *P. ballingallii* but irregular in *P. spodochroa*. Furthermore these two species are readily distinguished chemically as *P. spodochroa* contains medullary salazinic acid (K+ yellow-deep red) while *P. ballingallii* contains lobaric acid and the scabrosin derivatives (K-). At present this species is known only from the type collection.

Paraparmelia brownlieii Elix & Johnston, sp. nov. Figure 3

Species cum thallo ut in *Paraparmelia spodochroa* sed ab hac specie lobis apicibus subascedens et acidum hyposticticum, acidum hypoconsticticum et acidum hyposalazinicum continente differt.
Type. Australia. New South Wales. On open rock with no bush, top of Mt. Lindsay, [30°16'S, 150°11'E], 1440 m, *Sue Brownlie A65*, 1969; MEL 1023429-holotype.

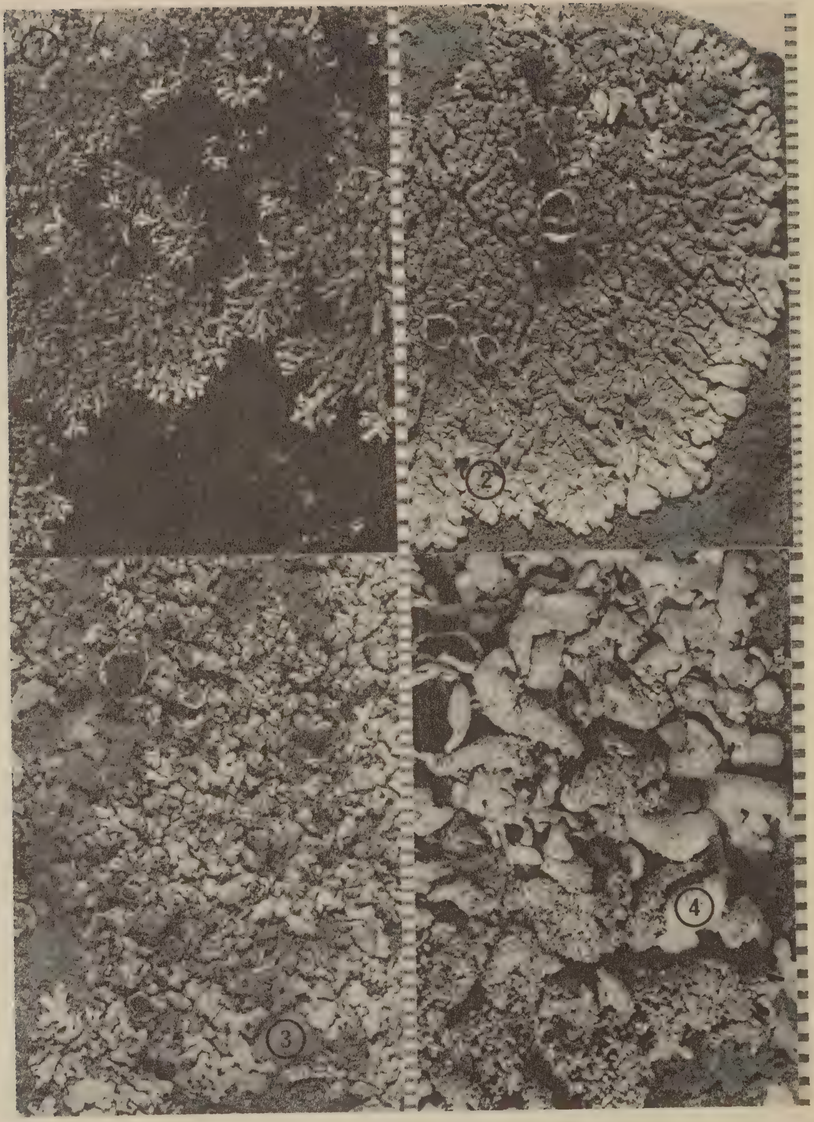
Thallus foliose, saxicolous, adnate to tightly adnate, pale ash-grey, forming irregular patches to 8 cm in diameter; *lobes* irregular to sublinear, narrow, 0.8-1.5 (-2.0) mm wide, irregularly branched, imbricate or barely so, subrotund at the apices, subascending at the apices. *Upper surface* plane, smooth, shiny and black margined at the tips, slightly arachnoid-pruinose subapically, becoming tangentially cracked, rugose and eventually areolate within, emaculate, lacking soredia and isidia; medulla white. *Lower surface* chestnut brown, moderately rhizinate, rhizines often grouped subapically, concolorous with the lower surface or darkening, simple or tufted at the tips. *Apothecia* adnate, to 4 mm diameter, the disc dark brown, concave at first then ± plane, margin thin, involute at first, then undulate; spores (8), colourless, ellipsoid, 7-8 x 4-6 μm. *Pycnidia* minute, black, punctiform, immersed; conidia bifusiform, 5.5-6.5 x 1-1.5 μm. *Chemistry*. Thallus K+ yellow; medulla K+ yellow- pale red, C-, P- ; containing atranorin, hypostictic acid (major), hypoconstictic acid (minor), hyposalazinic acid (trace).

Morphologically this new species resembles *P. spodochroa* (Kurok. & Filson) Elix & Johnston as both have similar, adnate thalli with a pale lower surface and lack soredia and isidia. However the apical lobes *P. brownlieii* are subascending but are plane and adnate in *P. spodochroa*. Furthermore these two species are readily distinguished chemically as *P. spodochroa* contains medullary salazinic acid (K+ yellow-deep red) while *P. brownlieii* contains hypostictic acid and hypoconstictic acid (K+ yellow-very pale red). *P. brownlieii* appears to be the fertile progenitor of the common isidiate species, *P. neoquintaria* (Hale) Elix & Johnston. This new species is known only from the type location.

Paraparmelia columbariensis Elix & Johnston, sp.nov. Figure 4

Species cum thallo ut in *Paraparmelia saginata* sed ab hac specie thallo laxe adnato, colore subtus brunneo vel atrobrunneo et acidum norsticticum continente differt.
Type. New South Wales. On sandstone rocks, summit of Pigeon House Mountain, 15 km west of Ulladulla, 720 m, *J. A. Elix 3950a*, 29.ix.1977; CBG-holotype.

Thallus foliose, saxicolous, adnate to loosely adnate, pale mineral grey, to 4 cm in diameter; *lobes* irregular, crowded and imbricate, 1.0-3.0 mm wide, subrotund at the apices. *Upper surface* shiny towards the apices, dull with age, emaculate, the margins blackened at the apices, isidiate; *isidia* dense in the centre of the thallus, scattered on the marginal lobes, globose at first, then cylindrical and inflated, especially at the apices, branched and becoming coralloid; medulla white. *Lower surface* dark brown to brown, often black-brown at the apices, shining, rugulose, very sparsely rhizinate, rhizines simple or tufted, robust, concolorous with the lower surface or darkening. *Apothecia* adnate to substipitate, to 4 mm in diameter, disc irregularly concave at first but becoming undulate-distorted with age, pale to dark brown; margin thick and involute at first, persistent, margin and amphithecium isidiate; spores (8), colourless, ellipsoid, 8-9 x 4.5-5.5 μm. *Pycnidia* common, punctiform, immersed, conidia bifusiform, 4-6 x 1 μm. *Chemistry*. Thallus K+ yellow; medulla K+ yellow-deep red, C-, P+ orange; containing atranorin, norstictic acid (major), salazinic acid (major), constipatic acid (minor), protoconstipatic acid (minor), connorstictic acid (trace), consalazinic acid (trace).



Figures 1-4. New species of *Paraparmelia:* 1, *Paraparmelia aranaea* (holotype in CBG); 2, *Paraparmelia ballingallii* (holotype in CBG); 3, *Paraparmelia brownlieii* (holotype in MEL); 4, *Paraparmelia columbariensis* (holotype in CBG). Scale in mm.

This new species appears to be related to *P. saginata* Elix & Johnston as both species have a pale lower surface, develop inflated isidia on the upper surface and produce salazinic acid as a major medullary acid. However they are separated clearly by their morphology as *P. saginata* has a tightly adnate thallus with a light tan to brown lower cortex, while *P. columbariensis* has a moderately adnate thallus with a dark brown to black-brown lower cortex. These two species are also distinguished chemically as *P. saginata* only contains salazinic acid and consalazinic acid in the medulla, while *P. columbariensis* contains substantial amounts of norstictic acid, constipatic acid and protoconstipatic acid in addition to salazinic acid. Furthermore these species have quite different ecological requirements and distinctive distributions: *P. saginata* is confined to the inland arid areas of South Australia and Northern Territory, while *P. columbariensis* is found on rocks in a moist hinterland area of southern New South Wales. At present it is known only from the type.

Paraparmelia fumarprotocetrarica Elix and Johnston, sp. nov. Figure 5

Species cum thallo ut in *Paraparmelia numinbahensis* sed ab hac specie thallo laxe adnato et acidum fumarprotocetraricum continente differt.
Typus. Australia. Queensland. On granite boulders in *Eucalyptus* forest, Settlement Road, Keperra (Brisbane), 27°28'S, 152°58'E, *c*. 200 m, *R. W. Rogers 2652*, 15.vi.1983; MEL-holotype.

Thallus foliose, saxicolous, adnate to loosely adnate, grey to dark grey, blackening with age, to 8 cm in diameter; *lobes* sublinear to irregular, subrotund at the apices, irregularly branched, highly imbricate, 1.0-2.0 mm wide, rarely developing narrower (0.4-1.0 mm wide) secondary lobes centrally. *Upper surface* plane for the most part, shiny, emaculate, slightly brown at the apices, the margin often blackening, isidiate; *isidia* dense in the centre of the thallus, scattered on the marginal lobes, cylindrical, slender, becoming coralloid-branched; medulla white. *Lower surface* black, sometimes brown at the margin, smooth, moderately to sparsely rhizinate, the rhizines simple, black. Apothecia and pycnidia not seen.
Chemistry: Cortex K+ yellow; medulla K+ pale yellow-brown, C-, P+ brick red; containing atranorin, fumarprotocetraric acid (major), succinprotocetraric acid (trace), protocetraric acid (trace), ursolic acid.

This new species resembles *P. numinbahensis* (Elix) Elix & Johnston in overall thallus morphology and the nature and the disposition of the isidia, but differs in being more loosely adnate and in medullary chemistry. Thus *P. numinbahensis* contains hypostictic acid, hypoconstictic acid and hyposalazinic acid (medulla P-) while *P. fumarprotocetrarica* contains fumarprotocetraric acid (medulla P+ brick red). *P. fumarprotocetrarica* appears to be the isidiate counterpart of *P. roderickii*. At present this new species is known only from the type collection.

Paraparmelia leucophaea Elix & Johnston, sp.nov. Figure 6

Species cum thallo ut in *Paraparmelia cerussata* sed ab hac specie thallo adnato, lobis imbricatis et acidum salazinicum et acidum consalazinicum continente differt.
Type. Australia. New South Wales. On granite rocks in wet sclerophyll forest, Brown Mountain, below the Lookout, 60 km south-east of Cooma, 850 m, *J. A. Elix 5458*, 6.xii.1978; CBG-holotype.

Thallus foliose, saxicolous, adnate, pale to dark grey, to 9 cm in diameter; *lobes* irregular, moderately imbricate, 1.0-2.0 (-4.0) mm wide, apices often subrotund,

occasionally developing narrower (0.5-1.0 mm wide), irregularly divided, markedly imbricate secondary lobes in the centre of the thallus. *Upper surface* smooth, dull, shiny and black-marginate at the apices, the centre becoming cracked and areolate with age, lacking soredia and isidia; medulla white. *Lower surface* brown to dark brown, becoming dark brown to brown-black at the margins, smooth for the most part, sparsely rhizinate, rhizines grouped subapically, simple or often tufted, robust, concolorous with the lower surface. *Apothecia* substipitate, to 7 mm in diameter, disc shallowly concave at first but becoming undulate-distorted with age, red-brown to dark brown; margin thin, crenulate, persistent; spores (8), colourless, ellipsoid, 7-9 x 4-6 µm. *Pycnidia* minute, plane, punctiform; conidia bifusiform, 5-6 x 1 µm.
Chemistry. Thallus K+ yellow; medulla K+ yellow becoming deep red, C-, P+ yellow-orange; containing atranorin, chloroatranorin, norstictic acid (major), salazinic acid (major), connorstictic acid (minor), consalazinic acid (minor).

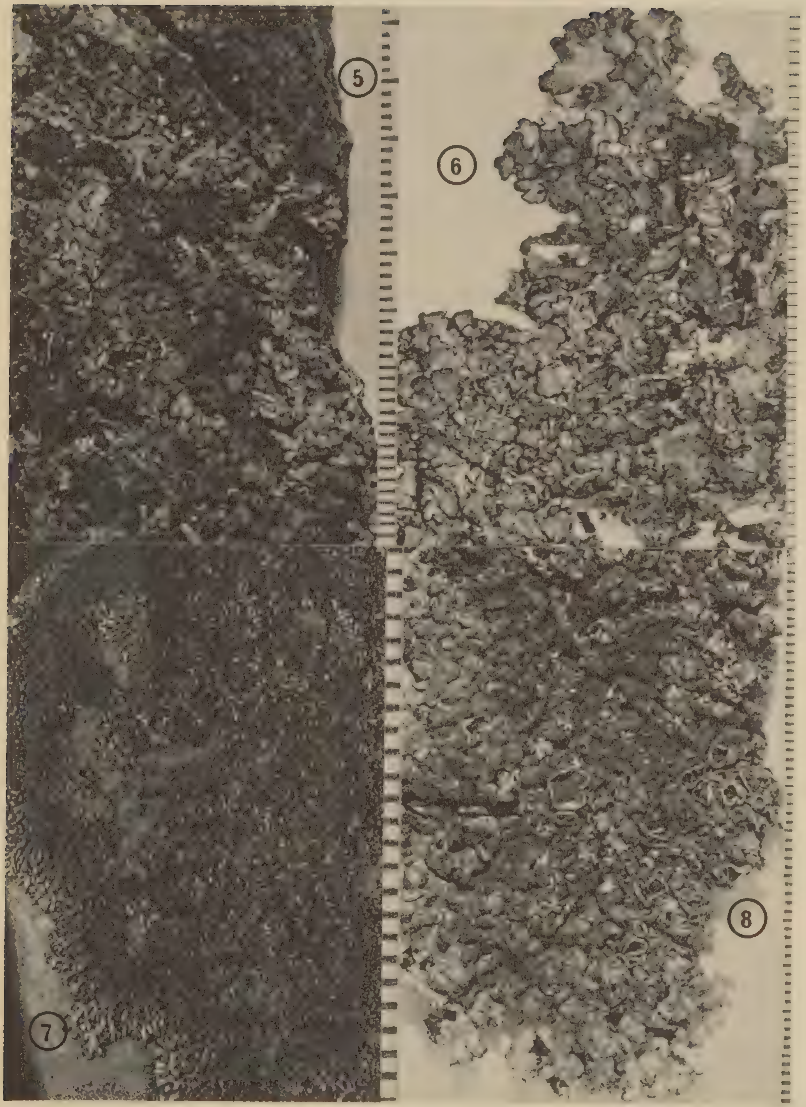
Morphologically this new species resembles *P. cerussata* (Kurok.) Elix & Johnston as both species have similar irregular lobes, a pale lower surface and lack soredia and isidia. However *P. cerussata* is more tightly adnate than *P. leucophaea* and the underside is pale tan, while in *P. leucophaea* the lower surface is brown to dark brown. These two species also have distinct geographic distributions within Australia. Thus *P. cerussata* is found in northern New South Wales (New England Tableland) while *P. leucophaea* is restricted to southern New South Wales and eastern Victoria, particularly in the Snowy Mountains and adjacent ranges. Furthermore these two species differ chemically: *P. leucophaea* contains atranorin, norstictic acid (major), salazinic acid (major), connorstictic acid (minor), and consalazinic acid (minor) while *P. cerussata* contains atranorin, norstictic acid and connorstictic acid [the type specimen contains no salazinic acid, contrary to the report of Kurokawa (Kurokawa 1985)].

Specimens Examined
NEW SOUTH WALES. On concrete borders of graves in subalpine grassland, Kiandra cemetery, Kosciusko National Park, *J. A. Elix 10810 & M. F. Day*, 3.xi.1982 (ANUC); on rocks in black *Acacia* scrub, Kosciusko National Park, Byadbo Range, 50 km west of Bombala, 1100 m, *J. A. Elix 10878A & M. F. Day*, 16.ii.1983 (ANUC). VICTORIA. On rocks in dry sclerophyll forest, Kelly Creek, Buldah road, 29.5 km north of Cann River, 37°18'S, 149°09'E, 300 m, *J. A. Elix 19556 & H. Streimann*, 27.ix.1985 (ANUC).

Paraparmelia neomongaensis Elix & Johnston, sp.nov. Figure 7

Species cum thallo ut in *Paraparmelia mongaensis* sed ab hac specie acidum norsticticum, acidum lobaricum, acidum connorsticticum et acidum hyposalazinicum continente differt.
Type. Australia. New South Wales. On exposed sandstone rocks in dry sclerophyll forest, trail to Pigeon House Mountain, 19 km west of Ulladulla, 35°20'S, 150°16'E, 460 m, J. A. Elix *21302 & H. Streimann*, 2.xii.1986; CBG-holotype.

Thallus foliose to subcrustose, saxicolous, tightly adnate, pale mineral grey but darkening to grey-black in older lobes, 1-3 cm in diameter, but sometimes coalesing into larger patches; *lobes* sublinear, crowded, contiguous within, barely imbricate, 0.2-0.6 (-0.8) mm wide, areolate at the centre but radiating at the periphery. *Upper surface* smooth, shiny and black margined towards the apices, inward becoming dull, fissured and rugose and eventually areolate, emaculate, lacking soredia and isidia; medulla white. *Lower surface* black, brown towards the margins, moderately rhizinate, rhizines simple. Apothecia and pycnidia not seen.
Chemistry. Thallus K+ yellow; medulla K+ yellow-deep red, C-, P+ orange-red; containing atranorin, chloroatranorin, norstictic acid (major), lobaric acid (major),



Figures 5-8. New species of *Paraparmelia:* 5, *Paraparmelia fumarprotocetrarica* (holotype in MEL); 6, *Paraparmelia leucophaea* (*J. A. Elix 10810 & M. F. Day* in ANUC); 7, *Paraparmelia neomongaensis* (holotype in CBG); 8, *Paraparmelia norcapnodes* (holotype in CBG). Scale in mm.

stenosporonic acid (major), colensoic acid (minor), connorstictic acid (trace),hyposalazinic acid (trace), divaronic acid (trace), unknown (trace).

Previously this species has been incorporated with *P. mongaensis* (Elix) Elix & Johnston as these two species have comparable morphology and can only reliably be distinguished by chemical means. Thus *P. mongaensis* contains only stenosporonic acid, colensoic acid and divaronic acid (K-) while *P. neomongaensis* contains additional norstictic acid and lobaric acid (K+ yellow-red). However as these two species have markedly different distribution patterns -*P. neomongaensis* is much rarer and has a very restricted distribution, while *P. mongaensis* ranges from north Queensland to Victoria, and also occurs in South Africa - they are considered distinct species (Elix, 1982). At present this new species is known only from the type locality.

Specimen Examined
NEW SOUTH WALES. Type locality, *J. A. Elix 21304 & H. Streimann,* 2.xii.1986 (ANUC).

Paraparmelia norcapnodes Elix and Johnston, sp. nov. Figure 8

Species cum thallo ut in *Paraparmelia atrocapnodes* sed ab hac specie acidum salazinicum deficiente differt.
Typus. Australia. New South Wales. On granite rocks in pasture, Countegany-Kybean Road, 36 km east-south-east of Cooma, 36°19'S, 149°30'E, 1000 m, *J. A. Elix 11450 & H. Streimann,* 15.xi.1983; CBG-holotype.

Thallus foliose, saxicolous, adnate to loosely adnate, grey to dark grey, blackening with age, to 10 cm in diameter. *Lobes* sublinear to irregular, subrotund at the apices, irregularly branched, imbricate, 1.0-3.0 (-4.0) mm wide, rarely developing narrower (0.4-1.0 mm wide) secondary lobes centrally. *Upper surface* plane for the most part, but developing transverse cracks with age and becoming rugose, shiny at the apices then dull, emaculate, slightly brown at the apices, the margin often blackening, isidiate; *isidia* dense in the centre of the thallus, scattered on the marginal lobes, cylindrical, slender, becoming coralloid-branched; medulla white. *Lower surface* black, sometimes brown at the margin, rugulose, moderately to sparsely rhizinate, the rhizines simple, black. *Apothecia* adnate to substipitate, to 5 mm in diameter, the disc concave then undulate-distorted, pale brown to dark brown, margin thin, involute at first then undulate, margin and amphithecium isidiate; spores (8), colourless, ellipsoid, 8-9 x 5-6 µm. Pycnidia not seen.
Chemistry: Cortex K+ yellow; medulla K+ yellow-deep red, C-, P+ orange; containing atranorin, norstictic acid (major), connorstictic acid (minor), constipatic acid (±).

This new species resembles *P. atrocapnodes* Elix & Johnston in overall thallus morphology and the nature and the disposition of the isidia, but differs in medullary chemistry. Thus *P. atrocapnodes* contains norstictic acid (submajor), connorstictic acid (trace), salazinic acid (major) and consalazinic acid (minor) while *P. norcapnodes* consistently lacks salazinic acid and consalazinic acid. These two species exhibit chemosyndromic variation but, as they maintain their chemical integrity (i.e. the ratio of salazinic:norstictic acids is either 2:1 or 0) even when sympatric, they are considered distinct taxa (Elix 1982). *P. norcapnodes* is a relatively common species in the hinterland ranges of south-eastern Australia. This species is considered the isidiate counterpart of *P. lithophila* (Kurok.) Elix & Johnston.

Specimens Examined
NEW SOUTH WALES. On granite rocks in dry sclerophyll forest, 55 km west of Dorrigo along the Armidale road, 1310 m, *J. A. Elix 2381*, 17.viii.1976 (ANUC); on

rocks in *Callitris* woodland, Broula Range, 5 km north of Bumbaldry, 35 km east of Cowra, 550 m, *J. A. Elix 8788*, 10.ix.1980 (ANUC); on rocks in *Callitris-Eucalyptus* woodland, Weddin Range, 15 km west of Grenfell, 33°54'S, 148°01'E, 430 m, *J. A. Elix 17686 & H. Streimann*, 17.x.1984 (ANUC).
AUSTRALIAN CAPITAL TERRITORY. On sandstone rocks in dry sclerophyll forest, western slopes of Black Mountain, Canberra, 760 m, *J. A. Elix 1030*, 2.vii.1975, *J. A. Elix 1274*; 20.x.1975 (ANUC); on granite rocks in subalpine woodland, along trail to Booroomba Rocks, 11 km south-west of Tharwa, 1280 m, *J. A. Elix 6224*, 11.vii.1979 (ANUC).
SOUTH AUSTRALIA. On rocks in *Eucalyptus* woodland, western slopes of Mt. Crawford, Mt. Lofty Ranges, 490 m, *J. A. Elix 3804, 3805*, 2.ix.1977 (ANUC).

Paraparmelia poeltii Nash, Elix & Johnston, sp. nov. Figure 9

Thallus adnatus ad saxa, cinerascens, 2 cm diametro; lobis angustatis et lineariter, 0.2-0.6 mm latis, planis; superne isidiis sorediisque destitutis; subtus nigra, dense rhizinatis, rhizinis concoloris, simplicibus. Thallus atranorinum, acidum protocetraricum et acidum virensicum continens.
Type. Venezuela. Cordillera de la Costa, Distr. Federal: Punta El Avila , über Caracas, gegen Gilla, 2200-2500 m, *B. & J. Oberwinkler & J. Poelt*, iii.1969; GZU-holotype.

Thallus small foliose to subcrustose, saxicolous, adnate to loosely adnate, pale ash-grey, forming irregular rosettes to 2 cm in diameter; *lobes* linear, radiating at the apices, ± imbricate, narrow, 0.2-0.6 mm wide, subdichotomously branched. *Upper surface* smooth and shiny, the older lobes becoming tangentially cracked, emaculate, black marginate towards the apices, lacking soredia and isidia; medulla white. *Lower surface* jet black, brown at the apices, densely rhizinate, rhizines black, simple or tufted at the tips, to 0.5 mm long, often projecting beyond the margins and appearing spuriously ciliate. Apothecia and pycnidia not seen.
Chemistry. Thallus K+ yellow; medulla K+ pale yellow-brown, C-, P+ orange-red ; containing atranorin, protocetraric acid (major), virensic acid (trace).

This distinctive new species is characterized by; the formation of tiny rosettes with pale ash-grey, very narrow (0.2-0.6 mm wide), linear, radiating lobes; the black lower surface and the production of protocetraric acid in the medulla. *P. subrugulosa* Elix & Johnston exhibits similar features, but differs in having broader (0.5-1.0 mm wide), tightly adnate, sublinear to irregular lobes with sparse rhizines. *P. poeltii* by contrast is moderately to loosely adnate, with narrower (0.2-0.6 mm wide), linear lobes and is densely rhizinate. At present this species is known only from the type.

Parapamelia roderickii Elix & Johnston, sp. nov. Figure 10

Species cum thallo ut in *Paraparmelia lithophila* sed ab hac specie acidum fumarprotocetraricum, acidum succinprotocetraricum et acidum protocetraricum continente differt.
Type. Australia. Queensland. On rocky outcrop, summit of Mt. French, Mt. French National Park near Boonah, 27°59'S, 152°37'E, > 200 m, *R. W. Rogers 8632*, 24.x.1985; MEL.

Thallus foliose, saxicolous, adnate to tightly adnate, pale ash-grey, forming irregular patches to 10 cm in diameter; *lobes* irregular to sublinear, narrow, 1.0-3.0 mm wide, irregularly branched, crowded and imbricate, subrotund at the apices. *Upper surface* plane, smooth, shiny and black-margined at the tips, becoming dull, tangentially

cracked, rugose and eventually areolate within, emaculate, lacking soredia and isidia; medulla white. *Lower surface* black, brown-black at the margins, moderately to sparsely rhizinate, rhizines black, robust, simple or tufted at the tips, to 0.5 mm long. *Apothecia* adnate, to 5 mm diameter, the disc dark brown, concave at first then ± plane or undulate, margin thin, involute at first, then undulate; spores (8), colourless, spuriously monoseptate (containing oil droplets), ellipsoid, 8-9 x 3.5-4.5 μm. *Pycnidia* minute, black, punctiform, plane; conidia bifusiform, 5.5-6.5 x 1-1.5 μm.
Chemistry. Thallus K+ yellow; medulla K+ pale yellow-brown, C-, P+ brick-red; containing atranorin, fumarprotocetraric acid (major), succinprotocetraric acid (trace), protocetraric acid (trace).

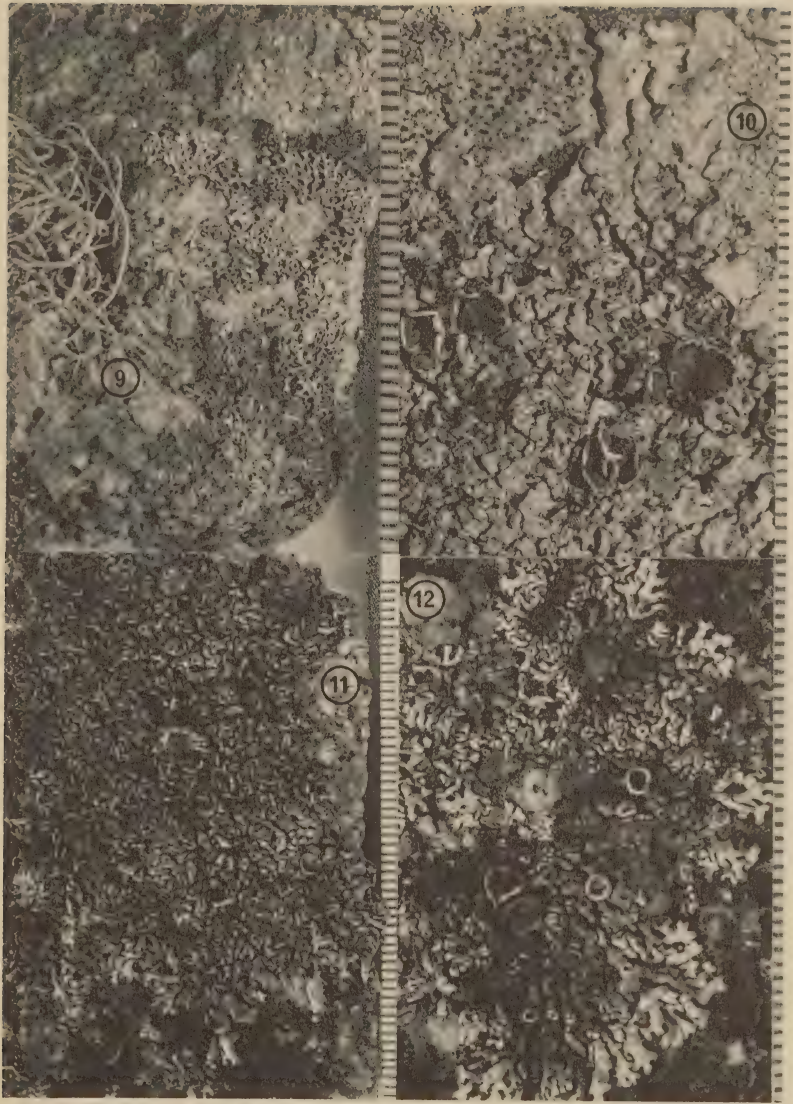
This distinctive new species is distinguished readily by the sublinear lobes which lack soredia and isidia, the black to brown-black lower surface and the production of fumarprotocetraric acid in the medulla. The other nonisidiate, saxicolous *Paraparmeliae* with comparable morphology known in Australasia include *P. lithophila* (Kurok.) Elix & Johnston, *P. lithophiloides* (Kurok.) Elix & Johnston, *P. subspodochroa* Elix & Johnston and *P. rugulosa* Elix & Johnston. The former three species are confined to the cool temperate areas of south-eastern Australia and contain salazinic acid, norstictic acid, or combinations thereof (medulla K+ yellow-deep red). On the other hand, *P. rugulosa* and *P. roderickii* react K+ pale yellow-brown, and seem to be confined to tropical and subtropical latitudes, although *P. rugulosa* has a more northerly distribution (Cooktown, 15°39'S). These two species are most reliably distinguished by their medullary chemistry, as *P. rugulosa* contains protocetraric acid and *P. roderickii*, fumarprotocetraric acid. *P. roderickii* is considered to be the fertile counterpart of *P. fumarprotocetrarica* Elix & Johnston. This species is named after its collector, the Australian lichenologist Dr. Roderick W. Rogers. At present this species is only known from the type locality.

Specimen Examined
QUEENSLAND. Type locality, *R. W. Rogers 8631*, 24.x.1985 (ANUC, CBG).

Paraparmelia sammyii Elix & Johnston, sp. nov. Figure 11

Thallus adnatus ad saxa, plumbeus, 6 cm diametro; lobis angustatis et lineariter elongatis, 0.3-0.6 mm latis, saepe revolutis et distortis; superne nitidis, isidiis sorediisque destitutis; subtus fusco- vel pallido-brunnescentibus, sparsim rhizinatis, rhizinis concoloris, simplicibus vel caespitosis. Thallus atranorinum et acidum 4-*O*-methylhypoprotocetraricum continens.
Type. Australia. Western Australia. On exposed granite rock in pasture, Yilliminning Rock, 20 km east of Narrogin on road to Harrismith, 32°56'S, 117°22'E, *J. A. Elix 21634 & M. V. Sargent*, 18.viii.1987; CBG-holotype, MEL-isotype.

Thallus foliose, saxicolous, loosely adnate to adnate, lead-grey, forming irregular rosettes to 6 cm in diameter; *lobes* linear-elongate, revolute and twisted, rarely imbricate, narrow, 0.3-0.6 (-1.5) mm wide, subdichotomously branched. *Upper surface* smooth and shiny at the apices, the older lobes occasionally becoming cracked, convex, emaculate, black marginate towards the apices, lacking soredia and isidia; medulla white. *Lower surface* pale tan to brown, darker towards the apices, sparsely rhizinate, rhizines often grouped subapically, concolorous with the lower surface, simple or tufted at the tips. *Apothecia* rare, substipitate, to 2 mm in diameter, disc concave at first but becoming flattened with age, dark brown; margin thin, entire, smooth; spores (8), simple, colourless, ellipsoid, 7-10.5 x 4.5-6 μm. *Pycnidia* numerous, minute, emergent, black; conidia bifusiform, 5.5-6.5 x 1 μm.
Chemistry. Thallus K+ yellow; medulla K-, C-, KC-, P-; containing atranorin, 4-*O*-methylhypoprotocetraric acid (major), hypoprotocetraric acid (minor), hypostictic



Figures 9-12. New species of *Paraparmelia:* 9, *Paraparmelia poeltii* (holotype in GZU); 10, *Paraparmelia roderickii* (holotype in MEL); 11, *Paraparmelia sammyi* (holotype in CBG); 12, *Paraparmelia sargentii* (holotype in CBG). Scale in mm.

acid (± trace).

This unusual species is characterized by the narrow, linear-elongate lobes which are revolute-twisted so that the lower surface often is seen from above.

Chemically *P. sammyii* is unique in the genus *Paraparmelia* as it is the only species which produces 4-*O*-methylhypoprotocetraric acid as the major medullary substance. This acid occurs in trace quantities in *P. arida* Elix & Johnston, an isidiate species, and is found in the related genus *Xanthoparmelia*. This species is named after the Australian lichenologist, Nathan Sammy who first collected it and brought it to our attention. At present this species is known only from the type locality.

Specimen Examined
WESTERN AUSTRALIA. Type locality, *J. A. Elix 21632, 21633, 21635, 21638, 21639, 21640, 21642 & M. V. Sargent*, 18.viii.1987 (ANUC); *N. Sammy 840863*, 5.x.1981 (PERTH).

Paraparmelia sargentii Elix & Johnston, sp. nov. Figure 12

Thallus adnatus ad saxa, cinerascens, 3.5 cm diametro; lobis angustatis et lineariter, 0.3-0.6 mm latis, convexis; superne pruinosis, isidiis sorediisque destitutis; subtus fusco- vel pallido-brunnescentibus, sparsim rhizinatis, rhizinis concoloris. simplicibus. Thallus atranorinum, acidum protoconstipaticum et acidum constipaticum continens.
Type. Australia. Western Australia. On exposed granite rock in pasture, Yilliminning Rock, 20 km east of Narrogin on road to Harrismith, 32°56'S, 117°22'E, *J. A. Elix 21641 & M. V. Sargent*, 18.viii.1987; CBG-holotype.

Thallus small foliose to subcrustose, saxicolous, adnate, pale ash-grey, forming irregular rosettes to 3.5 cm in diameter; *lobes* linear, radiating at the apices, rarely imbricate, narrow, 0.3-0.6 (-1.0) mm wide, subdichotomously branched. *Upper surface* smooth and shiny at the tips, the older lobes becoming centrally rugose and areolate, convex, emaculate, black marginate towards the apices, developing dense granular pruina subapically, lacking soredia and isidia; medulla white. *Lower surface* pale tan to brown, darker towards the apices, sparsely rhizinate, rhizines concolorous with the lower surface, simple or tufted at the tips, thick, to 0.2 mm long. *Apothecia* scattered, substipitate, to 3 mm in diameter, disc concave at first then undulate-distorted, pale brown to brown; margin thick, entire then ± cracked, pruinose; spores (8), (immature) simple, colourless, ellipsoid, 3.5 x 2 µm. *Pycnidia* numerous, minute, punctiform, slightly emergent, black; conidia bifusiform, 6-7 x 1 µm.
Chemistry. Thallus K+ yellow; medulla K-, C-, KC-, P- ; containing atranorin, protoconstipatic acid (major), constipatic acid (minor).

This new species is characterized by the formation of tiny rosettes with pale ash-grey, narrow (0.3-1.0 mm wide), linear, radiating lobes; the pale lower surface and the production of fatty acids in the medulla. *P. pinguiacida* Elix & Johnston exhibits similar features, but differs in having broader (0.5-1.5 mm wide), deep lead-grey, contiguous lobes.

Both species contain fatty acids from the same chemosyndrome but do show consistent differences in the concentrations of these compounds: *P. pinguiacida* contains dehydroconstipatic acid (major), pertusaric acid (minor), constipatic acid (± trace) and protoconstipatic acid (± trace); *P. sargentii* produces protoconstipatic acid (major), constipatic acid (minor). This species is named in honour of the Australian organic chemist and field companion, Melvyn V. Sargent. At present this species is known only from the type locality.

Specimen Examined
WESTERN AUSTRALIA. Type locality, *J. A. Elix 21635, 21636 & M. V. Sargent*, 18.viii.1987 (ANUC).

Paraparmelia sublineola Elix & Johnston, sp. nov. Figure 13

Species cum thallo ut in *Paraparmelia subtropica* sed ab hac specie colore subtus brunneo et acidum protocetraricum continente differt.
Type. Australia. Queensland. On granite rocks in dry sclerophyll forest, Ingham-Kangaroo Hills Road, 36 km SW of Ingham, 18°49'S, 145°53'E, 650 m, *J. A. Elix 20404 & H. Streimann*, 19.vi.1986; CBG-holotype.

Thallus small foliose, saxicolous, tightly adnate, pale grey to grey or darkening with age, to 5 cm in diameter; *lobes* sublinear-elongate, separate at the apices, ± contiguous within, barely imbricate, subdichotomously divided, 0.5-1.2 mm wide. *Upper surface* plane, shiny and black-margined towards the apices, becoming dull with age, emaculate, moderately isidiate; *isidia* globose to short-cylindrical, simple, often black-tipped, less than 0.2 mm high; medulla white. *Lower surface* pale brown to brown, blackening at the margins and the tips, moderately to sparsely rhizinate, rhizines simple, concolorous with the lower surface. Apothecia and pycnidia not seen.
Chemistry. Cortex K+ yellow; medulla K+ pale yellow-brown, C-, P+ red-orange; containing atranorin, protocetraric acid.

This characteristic species resembles *P. subtropica* Elix & Johnston in overall thallus morphology and the nature and distribution of the isidia. However the lower surface is pale brown to brown (black at the margins) in *P. sublineola,* but jet black in *P. subtropica*. Furthermore *P. sublineola* produces protocetraric acid as the medullary acid (K+ pale yellow-brown) while *P. subtropica* contains norstictic acid (K+ yellow-deep red). Morphologically *P. sublineola* closely resembles *P. maccauleyensis* (above), but the latter also differs chemically (containing norstictic acid and reacting K+ yellow-deep red). At present this species is known from several hinterland localities in north Queensland.

Specimens Examined
QUEENSLAND. On granite rocks in dry scleropyll forest with *Pandanus* and *Lantana*, Hervey Range, 45 km WSW of Townsville, 19°22'S, 146°28'E, 350 m, *J. A. Elix 20470 & H. Streimann*, 20.vi.1986 (ANUC).

Paraparmelia subrugulosa Elix & Johnston, sp. nov. Figure 14

Species cum thallo ut in *Paraparmelia mongaensis* sed ab hac specie lobis latioribus et acidum protocetraricum continente differt.
Type. Australia. Queensland. On granite rocks in *Eucalyptus-Casuarina* woodland, Helensvale-Rossville Road, 29 km south of Cooktown, 15°45'S, 145°15'E, 150 m, *J. A. Elix 17407 & H. Streimann*, 5.vii.1984; CBG-holotype.

Thallus small foliose, saxicolous, tightly adnate, pale grey to grey, to 3 cm in diameter; *lobes* irregular to sublinear-elongate, separate, barely imbricate, subdichotomously divided, (0.2-) 0.5-1.0 mm wide. *Upper surface* plane, smooth, shiny and black-margined towards the apices, becoming dull with age, emaculate, lacking soredia and isidia; medulla white. *Lower surface* black ± with narrow brown marginal zone, smooth, moderately to sparsely rhizinate, rhizines simple, black. Apothecia and pycnidia not seen.
Chemistry. Cortex K+ yellow; medulla K+ pale yellow-brown, C-, P+ red-orange;

containing atranorin, chloroatranorin, protocetraric acid.

This characteristic species resembles *P. mongaensis* (Elix) Elix & Johnston in overall thallus morphology but the lobes are broader (0.2-1.0 mm wide), separate and subradiating, while those of *P. mongaensis* are narrower (0.2-0.6 mm wide), contiguous and crowded. Furthermore *P. subrugulosa* produces protocetraric acid as the medullary acid (P+ red-orange) while *P. mongaensis* contains stenosporonic acid, colensoic acid and divaronic acid (P-).

P. rugulosa Elix & Johnston might be confused with *P. subrugulosa* as it also produces protocetraric acid, has a black lower surface and lacks soredia and isidia. However *P. rugulosa* has much broader lobes (2-3 mm wide), a markedly rugulose upper surface and contains minor quantities of medullary norstictic acid and virensic acid. *P. subrugulosa*, on the other hand, has a smooth upper surface, narrower lobes and lacks the accessory medullary acids. At present this species is known from several hinterland localities in north Queensland.

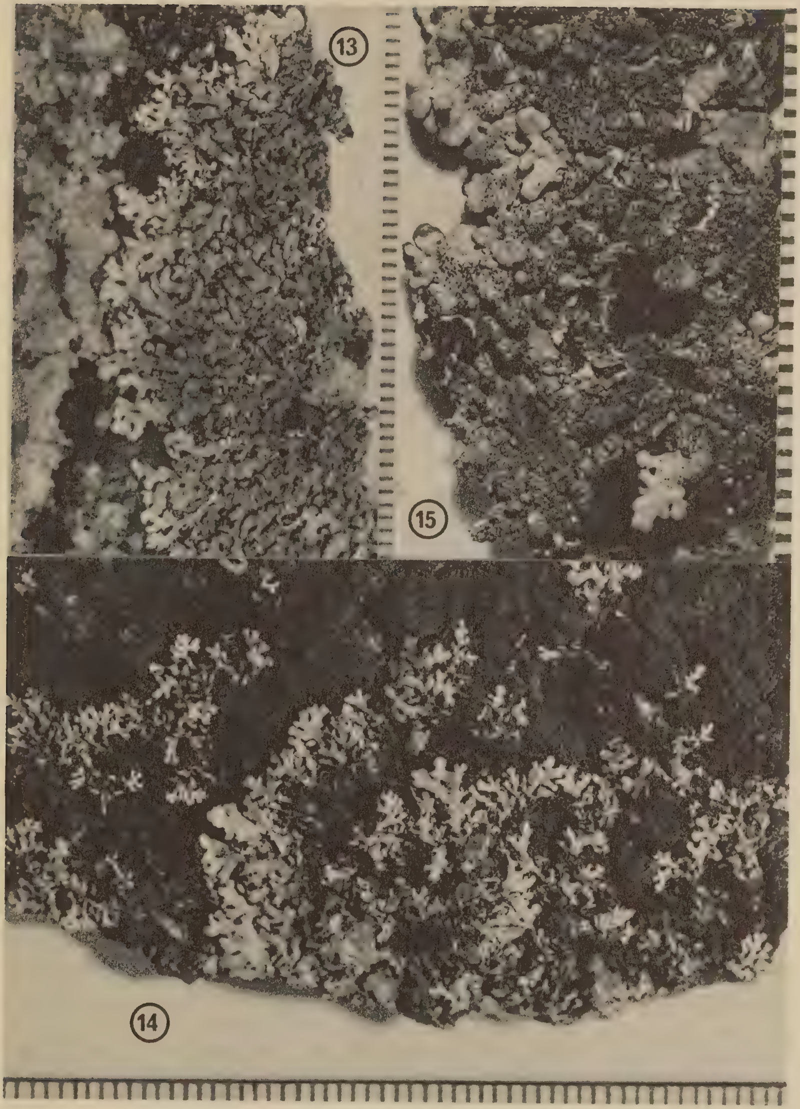
Specimen Examined
QUEENSLAND. On granite rocks in *Eucalyptus* dominated woodland, near summit of Mt. Leswell, 32 km south of Cooktown, 15°46'S, 145°15'E, 440 m, *J. A. Elix 17345 & H. Streimann*, 5.vii.1984 (ANUC).

Paraparmelia tropica Elix & Johnston, sp.nov. Figure 15

Species cum thallo ut in *Paraparmelia saginata* sed ab hac specie colore subtus nigro et acidum protocetraricum continente differt.
Type. Queensland. On granite rocks in *Eucalyptus* dominated woodland, near summit of Mt. Leswell, 32 km south of Cooktown, 440 m, *J. A. Elix 17364 & H. Streimann*, 5.vii.1984; CBG-holotype.

Thallus foliose, saxicolous, adnate, pale mineral grey, to 5 cm in diameter; *lobes* irregular, crowded and imbricate, 1.0-2.0 mm wide, subrotund at the apices. *Upper surface* shiny towards the apices, dull with age, emaculate, the margins blackened at the apices, isidiate; *isidia* dense in the centre of the thallus, scattered on the marginal lobes, globose at first, then elongating but inflated especially near the base, moderately branched but rarely becoming coralloid, brown-black apically, to 2 mm high; medulla white. *Lower surface* black to black-brown, chocolate brown at the apices, shining, smooth, very sparsely rhizinate, rhizines simple or tufted, robust, concolorous with the lower surface or darkening. Apothecia and pycnidia not seen.
Chemistry. Cortex K+ yellow; medulla K+ pale yellow-brown, C-, P+ red-orange; containing atranorin, protocetraric acid.

This new species appears to be related to *P. saginata* Elix & Johnston as both species have adnate thalli and develop inflated isidia on the upper surface. However they are separated clearly by their morphology: *P. saginata* has thalli with a light tan to brown lower cortex and isidia that are inflated at the apices; *P. tropica* has thalli with a chocolate brown to black lower cortex, and isidia that are inflated near the base. These two species also are distinguished chemically as *P. saginata* contains salazinic acid and consalazinic acid in the medulla (K+ yellow-deep red), while *P. tropica* contains protocetraric acid (K+ pale to dirty yellow-brown). *P. tropica* might also be confused with *P. aranaea* as both species have a black lower surface, isidia and medullary protocetraric acid. However the lobes of *P. tropica* are broader (1-2 mm wide), crowded and imbricate and the isidia are large (to 2 mm high), branched and inflated, while in *P. aranea* the lobes are narrow (0.2-1.2 mm wide), separate and the isidia are simple, short (to 0.2 mm high), cylindrical and not inflated. At present it is known only from the type.



Figures 13-15. Species of *Paraparmelia:* 13, *Paraparmelia sublineola* (holotype in CBG); 14, *Paraparmelia subrugulosa* (holotype in CBG); 15, *Paraparmelia tropica* (holotype in CBG). Scale in mm.

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MYCOTAXON

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A NEW SPECIES OF *AMANITA* FROM NORTH AMERICA: *AMANITA LEVISTRIATA*

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Summary

During one week of collecting at the 1987 meetings of the North American Mycological Association in Gulfport, MS, several collections of an undescribed *Amanita* were made at different locations. The presence of nonamyloid spores in conjunction with a bulbous base placed this organism in Section *Amanita*. The size, pileus color, and nonstriate to slightly striate pileus margin were, in combination, strikingly different from other organisms in this section. Therefore, *Amanita levistriata* is described as new and is assigned to Section *Amanita*, Subgenus *Amanita*.

Amanita levistriata Jenkins, sp. nov. (Fig. 1 & 2).

Pileus 17-30 mm latus, tenuis, convexus dein plano-convexus, margine nonstriata vel leviter striato, siccus vel subvisicidus, melleus, margine interdum pallide ochraceo, discus decoloratus vetustate, fragmentis volvae floccosis, ochraceis dispersus. Lamellae liberae, subconfertae, albae. Stipes 29-42 mm longus, 5-8 mm crassus, albidus, subfibrillosus, bulbo submarginato vel marginato. Volva ochracea, limbo 1-2 mm lata, floccoso. Annulus membranaceus, albus vel pallide ochraceus, superus. Sporae (6.7) 7.8-9.3 (9.97) x (5.5) 6.3-7.8 (9.5) µm, globulosae vel subglobulosae, nonamyloideae, albidae.

Etymology: From latin leviter = slightly and striatus = striated.

Holotypus: Black Creek Wilderness Area, Perry Co., MS, 16. vii. 87, David T. Jenkins, 2790(DTJ).

Basidiocarps small, solitary. PILEUS: 17-30 mm diam, convex when young to plano-convex at maturity; margin slightly incurved when young, nonstriate to slightly striate, flesh occasionally splitting between gills; pileipellis membranous, easily separable from pileus flesh, glabrous, dry to very slightly viscid; disc honey-colored, 4C8, (Kornerup & Wanscher, 1978) to yellowish, 4A5, becoming lighter, 4A4 to 4B8 toward margin, in older specimens disc fading to 4B6 and margin to 4A2 to 4A3; flesh white, unchanging, thin, up to 2 mm on disc, tapering toward margin, pale yellowish, 4A2 to 4A3, beneath pileipellis; remnants of universal veil as delicate floccose patches, 4A5 to 4B8, randomly distributed, detersile, becoming flocculence toward margin. LAMELLAE: moderately crowded, free, white, edges flocculose; lamellulae moderately abundant, abruptly truncate. STIPE: 29-42 x 5-8 mm, tapering slightly toward expanded apex, glabrous to slightly fibrillose, whitish, becoming pale yellowish upon handling, lumen stuffed, flesh white; basal bulb turbinate, up to 19 x 16 mm, submarginate to marginate, whitish; remnants of universal veil as a floccose rim at bulb

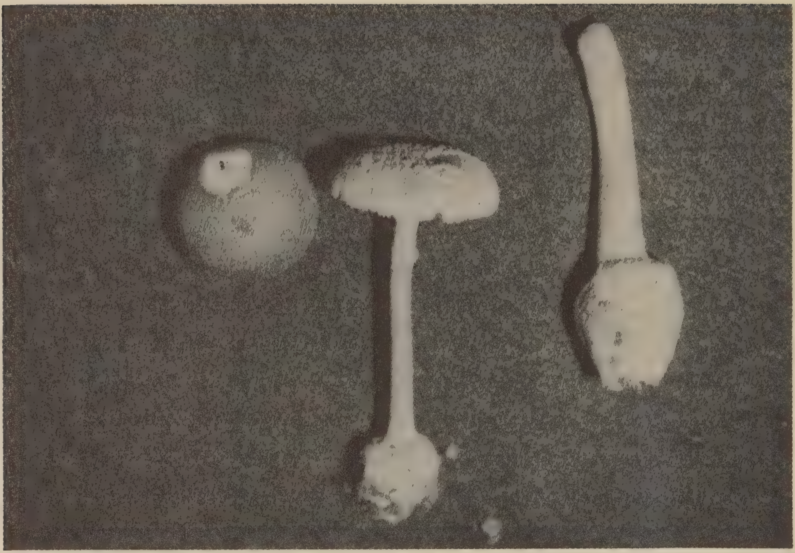

Fig. 1. *Amanita levistriata* 2790(DTJ).

apex, with flocculence on bulb margin, detersile, 4A5 to 4B8; partial veil very thin, membranous, superior, persistent, frequently adhering to stipe, whitish to very pale yellow, striate above, slightly floccose on underside. Basidiocarps having no distinct odor or taste.

PILEIPELLIS: suprapellis gelatinous, hyphae radially interwoven, but frequently difficult to recognize; subpellis only slightly gelatinized, hyphae moderately branched, radially interwoven, pigmented, 2.5-7 μm diam, without clamps; no inflated cells. PILEUS TRAMA: filamentous hyphae undifferentiated, moderately branched, 2.5-6.5 μm diam, without clamps; inflated cells abundant, elliptic, clavate to fusiform, terminal, up to 155 x 31 μm. LAMELLA TRAMA: bilateral; filamentous hyphae undifferentiated, without clamps, 2-7.5 μm diam, moderately branched; inflated cells clavate to fusiform to slightly irregular, terminal, up to 145 x 32 μm. SUBHYMENIUM: ramose to slightly inflated ramose, clamps occasional. BASIDIA: up to 48 x 4-12 μm, clavate, 4-sterigmate, thin-walled, without clamps. UNIVERSAL VEIL: Pileus - filamentous hyphae sparse, branching infrequently, 2.5-6 μm diam, without clamps; oleiferous hyphae sparse; inflated cells composing most of the tissue, mostly globose to subglobose, up to 69 x 69 μm, occasionally subtended by elliptic to clavate cells, up to 63 x 25 μm, usually in short, terminal, intertwined chains: Basal bulb - inflated cells and filamentous hyphae equally abundant; hyphae infrequently branched, 3-7.5 μm diam, without clamps; oleiferous hyphae sparse; inflated cells similar to those of pileus universal veil, but with a greater number of small, subtending elongate cells, up to 49 x 20 µm. STIPE TRAMA: filamentous hyphae abundant, undifferentiated, moderately branched, 2.5-8.5 µm diam, without clamps; inflated cells slenderly clavate, terminal, up to 320 x 21 µm, longitudinally oriented. PARTIAL VEIL: almost completely filamentous hyphae, undifferentiated, moderately branched, interwoven, 2-7.5 µm diam, without clamps; inflated cells clavate, terminal, up to 24 x 10 µm.

BASIDIOSPORES: (6.7) 7.8-9.3 (9.97) x (5.5) 6.3-7.8 (9.5) µm (E = 1.0-1.31; E^m = 1.11), globose to subglobose, adaxially flattened, thin-walled, hyaline, nonamyloid, contents guttulate, apiculus sublateral, truncate; white in deposit.

Habitat and distribution: terrestrial, solitary, sandy soil, mixed coniferous and deciduous forests, to date known only from Mississippi.

Collections examined: Packard Pond, near Gulfport, MS, 15. vii. 87, David T. Jenkins 2822(DTJ)*; Black Creek Wilderness Area, Perry Co., MS, 16. vii. 87, David T. Jenkins 2790(DTJ); Black Creek Wilderness Area, Perry Co., MS, 16. vii. 87, James Tinius 2793(DTJ); Black Creek Trail, Perry Co., MS, 17. vii. 87, Rod Tulloss, 7-17-87-D(RET)**; Parkers Lake, Jackson Co., MS, 17. vii. 87, C. Skeffington, 7-17-87-H (RET); Jackson Co., MS, 18. vii. 87, Igor Alexander, 7-18-87-E(RET); Parkers Lake, Jackson Co., MS, 18. vii. 87, A. G. Parks, 7-18-87-I (RET).

Discussion: Based upon the characters of nonamyloid spores, a distinct basal bulb, and usually striations on the pileus margin, *Amanita levistriata* is placed into Section *Amanita*, Subgenus *Amanita*. This species can be distinguished from others in this section by the following combination of characters: the small fruitbody size, the golden-yellow pileus which frequently pales with age, the pale yellowish, floccose patches of universal veil on the pileus, the very slight marginal striations of the pileus, the thin, superior annulus, the submarginate to marginate basal bulb with a slight rim of universal veil at the apex, and the globose to subglobose basidiospores.

For the members of Section *Amanita* in North America the presence of globose spores is not common. Of the 22 recognized taxa (Jenkins, 1986), only 4 have such spores: *Amanita crenulata, Amanita farinosa, Amanita frostiana,* and *Amanita macrospora*. Based upon small fruitbody size and pileus color only two of these might be comfused with *Amanita* levistriata, viz., *Amanita frostiana* and *Amanita macrospora*. Both have orangish or yellowish pileus color and similar small size. *Amanita frostiana*, however, has a white stipe, an ovoid basal bulb with yellowish, detersile, floccose patches of universal veil, and has much orange in the pileus color. Separation from *Amanita macrospora* can be achieved due to its pale orangish-yellow stipe and its white universal veil remnants, as warts on the pileus and a tightly booting free margin on the basal bulb.

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* DTJ = Herbarium of David T. Jenkins

** RET = Herbarium of Rod E. Tulloss

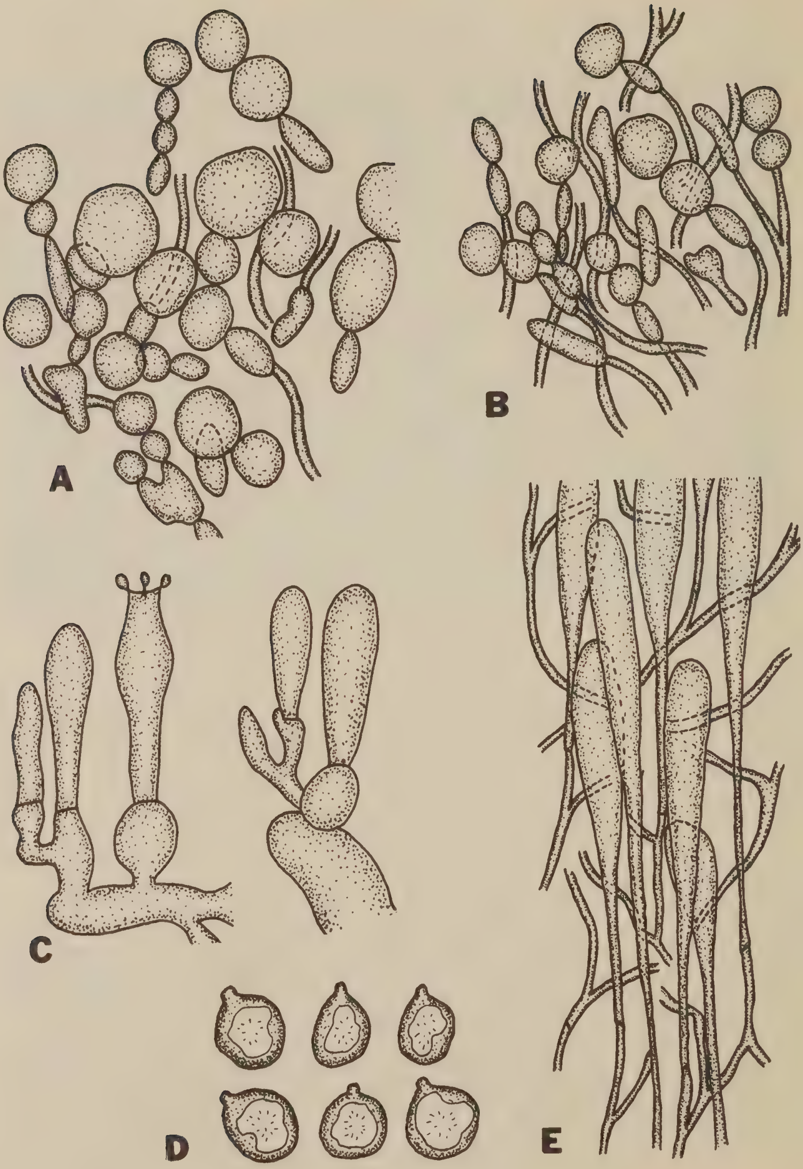

Fig. 2. *Amanita levistriata*. A. Volval material from pileus. B. Volval material from basal bulb. C. Basidia & subhymenium. D. Basidiospores. E. Stipe trama.

The organism that *Amanita levistriata* appears to most closely resemble is *Amanita pulchella* Imai (1933) sensu Hongo (1958). This Japanese mushroom possesses several macroscopic characters which are very similar to those of *Amanita levistriata*. These include pileus and stipe color, universal veil color and orientation, and the color and location of the annulus. *Amanita pulchella* can be distinguished due to its tuberculate-striate to sulcate-striate pileus margin, the subbulbous stipe base with friable universal veil material, spores that are broadly elliptic to elliptic, basidia which are 2,3,4-sterigmate, and the abundance of oleiferous hyphae in the universal veil.

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AMANITA SINICOFLAVA: A NEW SPECIES FROM EASTERN NORTH AMERICA

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Summary

Amanita sinicoflava is described as new with a range from Maine to southwestern Virginia. Previously unavailable, detailed microscopic data on collections of *A. mortenii* Knudsen & Borgen and *A. submembranacea* (Bon) Gröger are supplied for comparison.

Amanita sinicoflava Tulloss sp. nov. Holotypus: New Jersey, Sussex County, Stokes State Forest, New Jersey Mycological Association foray participant 10-6-85-A (NY[1]).

Etymology: *sinico-flavus*, Chinese yellow.

Pileus suboliveo-alutaceus vel brunneo-olivaceus, 25-66 *mm in mensura diametrica, umbonatus, primo ovoideus, sed deinde qui fit late campanulatus vel late plano-convexus, margine striata, nonappendiculata; materies volvica infrequens, alba, cinerea ut senescit. Lamellae condensae, liberae, albae vel cremeae. Stipes* 60-135 × 4-12 *mm, pallidus. Volva submembranacea, alba, cinerea ut senescit,* 26-39 *mm alta. Basidiae tetrasterigmaticae; fibulae absentes. Sporae* (8.0-) 9.1-12.2 (-15.4) × (7.0-) 8.4-11.5 (-15.4) *μm, globulosae vel subglobulosae, nonamyloideae.*

Belonging to section *Vaginatae*, *Amanita sinicoflava* (Fig. 1) has a small to medium sized basidiocarp with a pale olive-tan to brownish olive, umbonate pileus with striate margin; an exannulate, pallid to pallidly concolorous stipe sometimes decorated with darkening fibrils; a graying membranous to submembranous volva as a basal sac; and globose to subglobose spores. At many forays one finds it classified as *A. fulva* (Schaeffer) Persoon; however, macro-characters alone serve to separate them. Microscopically, the structure of the universal veil is of interest. Very thin layers of longitudinally oriented hyphae make up very delicate inner and outer layers; the bulk of the tissue contains plentiful inflated cells which contribute to weakness and collapse in age very similar to those phenomena in the universal veil of "*A. inaurata*" ss. Peck.[2]

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[1]

DTJ - Private herbarium of D. T. Jenkins, University of Alabama, Birmingham, U.S.A.
IB - Innsbruck University Herbarium, Austria.
L - Rijksherbarium, Leiden, The Netherlands.
NY - Herbarium of The New York Botanical Garden, Bronx, U.S.A.
TBor - Private herbarium of T. Borgen, Paamiut, Greenland.

All collections with no herbarium location cited are in the author's private herbarium. The author's collection numbers are composed of three numbers (month, day, year) and a string of characters which serve to distinguish fungi collected on a given day.

PILEUS: 25-66 mm diam, from pale olive-tan to olive-yellow to curry to brownish olive sometimes darker in disk (4B3, browner than 4B3, 4-5C4, 4-5C8, browner than 4C4, browner than 4C8, much more olive than 5C4, 5F7-8 (over disk in one specimen), 6D4[3]), sometimes pigmentation developing/darkening after rupture of universal veil, occasionally paler to cream at margin, at first ovoid with umbo, expanding to broadly subcampanulate to convex to plano-convex with downcurved margin, always retaining small pronounced umbo, dull, subviscid to dry; margin striate ((0.3R-) 0.4R (-0.5R)); universal veil not present or rarely as one or very few small whitish to sordid patches graying with age; context (1-) 2.5-4 mm thick at disk, white to off-white, sometimes darker or yellowish under disk, unchanging, thinning evenly for about 60-80 per cent of the radius, then very thin to margin. LAMELLAE: close to subcrowded, 4-7.5 mm broad, free to narrowly adnate, occasionally with minute decurrent tooth, white to off-white to cream occasionally with faint orangish tint in mass, white to pale cream in side view, unchanging, after drying cream to pale tan sometimes with darker margin to light brown (between 3A3 and 4A3 to 4A3 to 4-5A4 to 5B4-5 to 5C-D4); margin minutely fimbriate (lens); lamellulae in many ranks most longer than half pileus radius, truncate to subtruncate to subtruncate with small to broad attenuate tooth at attachment to pileus. STIPE: 60-135 × 4-12 mm, white to off-white to pale cream to grayish, palest toward apex, becoming yellowish to tannish to brownish from handling, narrowing upward, flaring at apex, without bulb; surface longitudinally striate or faintly so at least near base, fibrillose for most of length, fibrils concolorous with pileus or paler or slightly sordid, coloring/darkening with exposure and handling, minutely punctate/pulverulent near apex, occasionally with faint lines at apex; context white, unchanging to rarely becoming brownish, larvae tunnels concolorous to rarely sordid tan, hollow with occasional white, cottony stuffing; central cavity 3-5.5 mm diam; exannulate; universal veil white to whitish at first becoming gray with exposure or handling, sometimes with small rusty or brick-red spots, interior pale orangish or pinkish becoming gray, submembranous to membranous, saccate to limbate, at first flaring above a constriction at about mid-height of sac with interior longitudinally pleated above point of constriction, collapsing on stipe with age, occasionally in large patches or smears or a ring on lower stipe and leaving only lower portion or very little of sac, highest point of limb reaching 26-39 mm from stipe base; thin, fibrillose, cottony internal limb at about point of constriction of sac rarely seen. Odorless. L-tyrosine spot test for tyrosinase (Marr, 1979) positive.

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[2] Since the synonymy of *A. ceciliae* (Berkeley & Broome) Bas and the North American "*A. inaurata*" is not firmly established, I distinguish them for the purposes of this discussion.

[3] Color codes are from (Kornerup & Wanscher 1978). Regrettably this resource does not prove completely satisfactory in rendering the color of *Amanita sinicoflava*.

PILEIPELLIS: 40-70 µm thick, composed of undifferentiated, filamentous hyphae interwoven, subradially arranged, sometimes gelatinizing; branching oleiferous hyphae nonradially arranged; pigment intracellular (not dissolving in water or ethanol), evenly distributed, not becoming guttulate in 2% KOH or in Melzer's Reagent. PILEUS CONTEXT: branching, undifferentiated, filamentous to inflated hyphae, 2.1-16.1 µm diam, interwoven; inflated cells to 62.3 × 25.9 µm; branching, oleiferous hyphae 2.1-12.2 µm diam, plentiful. LAMELLA TRAMA: bilateral; branching, undifferentiated, filamentous to somewhat inflated hyphae 1.5-14.0 µm diam; inflated cells 28.4-68.6 × 17.6-44.1 µm; branching, oleiferous hyphae common, 2.8-6.6 µm diam. SUBHYMENIUM: frequently branching hyphae with closely spaced septa—subcellular to subramose.[4] BASIDIA: (41.7-) 49.0-62.3 × 12.6-16.8 (-21.0) µm, clavate to broadly clavate, 4-spored to rarely 1- or 2-spored, thin-walled; no clamps seen. UNIVERSAL VEIL: on stipe base, interwoven, branching, undifferentiated, filamentous hyphae, 2.1-5.6 (-7.0) µm diam; branching, oleiferous hyphae singly or in tangled clusters, up to 10.5 µm diam; plentiful globose to subglobose to ellipsoid inflated cells single or, infrequently, in chains of two (rarely three), terminal, difficult to reinflate, 19-45 (-60) × 15-39 (-46) µm; tissue becoming slightly denser toward inner surface; outer surface occasionally with somewhat scattered remnant patches of a layer (one or two hyphal diameters thick) of longitudinally arranged, undifferentiated, filamentous hyphae up to 7 µm diam; inner surface also occasionally having such remnants, but here gelatinizing or nearly entirely gelatinized; no clamps seen. STIPE CONTEXT: acrophysalidic; branching, filamentous, undifferentiated hyphae 2.8-5.6 µm diam; acrophysalides very long and narrow to 635 × 50 µm; occasional, branching, oleiferous hyphae 5.6-9.1 µm diam; no clamps seen. All tissues pale yellow in ammonium hydroxide.

BASIDIOSPORES: [505 from 26 specimens] (8.0-) 9.1-12.2 (-15.4) × (7.0-) 8.4-11.5 (-15.4) µm, (average length per collection = 9.5-11.1 (-11.7) µm; average length (overall) = 10.6 µm; average width per collection = (8.7-) 9.5-10.8 µm; average width (overall) = 10.0 µm; Q = 1.0-1.14 (-1.26); average Q per collection = 1.04-1.10; average Q (overall) = 1.06), inamyloid, thin-walled, hyaline, globose to subglobose to occasionally broadly ellipsoid, frequently slightly adaxially flattened; contents guttulate; apiculus sublateral to rarely lateral, truncate conic to cylindric, can be rather large relative to spore size; white in deposit.

Distribution and habitat: Solitary to occasionally subgregarious, June to October, at 10-1,000+ m elev., in a variety of habitats from Vermont to southwestern Virginia. Apparently with a wide variety of mycorrhizal symbionts. On the summit of Mt. Greylock (Massachusetts) this fungus appeared in a thin layer of damp loam over rock in moss under *Abies balsamea* (L.) Miller. The Mariaville, New York collection was made in wet loam in a mixed deciduous woods composed of *Acer sp., Carya sp., Quercus coccinea* Muenchh. and *Quercus rubra* L. The Floodwood, New York collection was made in duff over acid, glacial out-wash sands under *Tsuga canadensis* (L.) Carr, *Fagus grandifolia* Ehrh., and *Prunus sp.* The Adams, Massachusetts collection was made in loam under *Acer sp.*, *Fraxinus sp.*, *Betula papyrifera* Marsh, and scattered *Fagus grandifolia.* At the Shark River site, *A. sinicoflava* has been found both in typical, sandy, oak-pine barrens (*Quercus spp.* and *Pinus rigida* Mill.) and in sandy soil in deciduous woods (*Acer rubrum* L., *Q. alba* L., *Q. velutina* Lam., *Rhododendron sp.*, and *Spirea sp.*). In Stokes State Forest, the larger associated vascular plants were northern hardwoods and hemlock (*Betula lutea* Michx. f., *Tsuga canadensis*, *Tilia sp.*, and *Ulmus sp.*). No data is available on vascular plants in the area of the Vermont or Virginia collections. In addition to the collections listed below, I have seen this distinctive fungus in West Virginia and Maine; regrettably, no collections from these states have been preserved.

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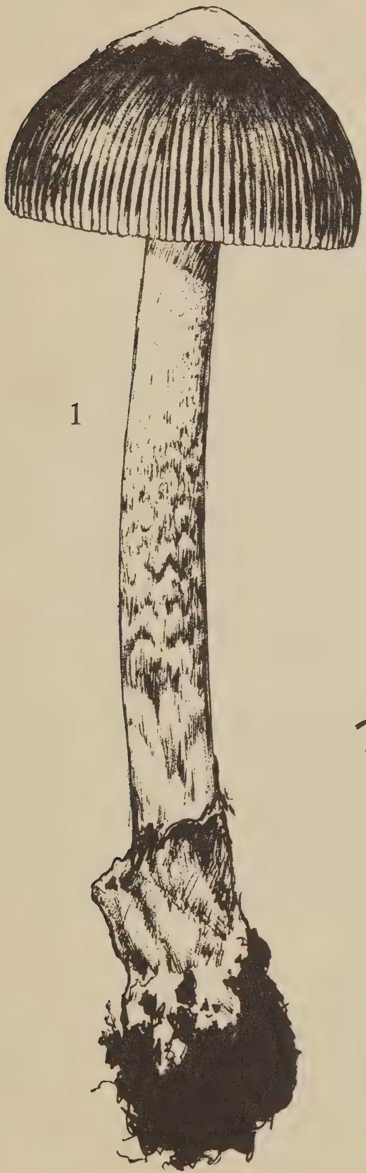
[4] Following C. Bas' application in the case of *A. subsolitaria* (Murrill) Murrill. See Fig. 11, p. 319 of (Bas, 1969).

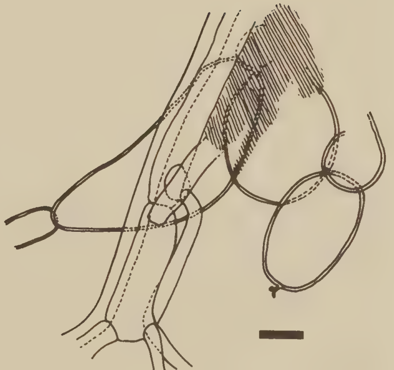
Collections examined: **UNITED STATES OF AMERICA**, MASSACHUSETTS, Berkshire Co., Adams, M. A. King & R. E. Tulloss 8-15-86-C (L), Balance Rock St. Pk., Rhoda Roper 8-15-86-L, Cheshire, Camp Mohawk, S. Sheine 8-15-86-F, summit of Mt. Greylock, R. E. Tulloss 8-17-86-A, border Hampshire & Hampden Cos., Mt. Tom St. Reservation, E. Greer 9-27-86-EG8; NEW JERSEY, Mercer Co., Hopewell, R. E. Tulloss 7-6-81-B, 7-7-81-C, 7-18-84-D, Monmouth Co., Shark River Co. Pk., Susan Hopkins 7-8-84-F, R. E. Tulloss 8-28-85-D, 8-28-85-F, Bruce Vansant 8-3-86-H, Sussex Co., Stokes St. For., M. A. King & R. E. Tulloss 6-15-85-A, NJMA member 10-6-85-A (holotype, NY), Wallpack Center, Neal Macdonald 10-6-85-E; NEW YORK, Essex Co., North Elba, Northeast Mycological Foray (NEMF) participant 8-21-87-L (DTJ), Franklin Co., Floodwood, Joe Arnold 8-22-87-E, Harrietstown, Smith 8-21-87-K (DTJ), Hamilton Co., Raquette Lake, Bill Roody 8-21-87-P, Otsego Co., Arnold St. For., Ray Fatto 8-16-85-C, Schenectady Co., Mariaville, M. A. King & R. E. Tulloss 8-18-86-C; PENNSYLVANIA, Pike Co., Pocono Environmental Educ. Ctr., M. A. King & R. E. Tulloss 6-20-81-A, 6-20-81-H; VERMONT, Bennington? Co., NEMF 1981, NEMF participant 8-30-81-A, Pownal Co., NEMF '81, NEMF participant 8-29-81-D; VIRGINIA, Grayson Co., Grayson Highlands St. Pk., Cabin Creek Trail, 9.ix.1986 Robert S. Williams 323.

DISCUSSION

In examining the universal veil tissue, I found very thin patches of longitudinally arranged hyphae on the outer surface. This character is liable to be noted only when a scalp of the volval sac is examined. The feature could be absent or unrecognizable in a longitudinal section especially in the portion of the volval sac which is stretched the most by the expansion of the pileus. In this area, the superficial layer is stretched so that gaps are opened in it; and it has the appearance of an expanded, net bag. Atkinson (1914) finds that tissues in the universal veil of *A. vaginata* ss. Atk. become progressively denser from the outer surface inward and notes the absence of an outer, entirely hyphal layer such as is found in *A. sinicoflava*. Atkinson knew of homologous structures in other agarics; for he cites the presence of ''radial'' hyphae found on the outer surface of the universal veil of *Lepiota clypeolaria* (Bull. ex Fr.) Kummer. As a check, I examined the outer surface of the universal veil in a specimen of *A. fulva* (collection 7-7-85-D). I found that the surface exhibited largely longitudinally oriented, but sometimes disoriented, partially gelatinizing hyphae in fascicles. Further pursuit of this character in other taxa may prove taxonomically valuable.

1





2

Fig. 1 *Amanita sinicoflava.* Tulloss 8-29-81-D [×1.6]. Fig. 2 *A. mortenii.* Universal veil tissue from volval sac showing thick-walled elements (Borgen TB.85.257). The bar in Fig. 2 represents 10 µm.

There are two taxa which closely resemble *A. sinicoflava* macroscopically: *A. mortenii* Knudsen & Borgen (from Greenland) and *A. submembranacea* (Bon) Gröger (subalpine, from Europe). I was able to obtain material representing both of these taxa; since neither has been described in detail microscopically, I include here the results of my observations.

Amanita mortenii Knudsen & Borgen. 1987. *Arctic and Alpine Mycology II*: 244.

PILEIPELLIS: 100-130 µm thick, composed of undifferentiated, filamentous hyphae 1.0-7.0 µm diam (mostly less than 3.0 µm diam), densely interwoven, subradially arranged, partially gelatinizing; branching, oleiferous hyphae 2.4-5.2 µm diam, not radially arranged. PILEUS CONTEXT: branching, undifferentiated, filamentous hyphae 3.5-10.5 µm diam, interwoven, some appearing to have thickened walls; oleiferous hyphae to 12.2 µm diam present; inflated cells terminal, mostly elongate, sausage shaped or elongate ventricose, also clavate to broadly clavate to barely inflated, to 159 × 49 µm, less commonly subglobose to broadly ellipsoid, to 52 × 42 µm, thick-walled. LAMELLA TRAMA: bilateral; inflated cells mostly ellipsoid to elongate to irregular, some subglobose, to 83.3 × 32.9 µm, in chains; frequently branching, filamentous, undifferentiated hyphae 2.4-5.6 µm diam; oleiferous hyphae present to 5.9 µm diam. SUBHYMENIUM: cellular (small subglobose cells terminal on chains of larger inflated cells). BASIDIA: 54.9-75.6 (-81.5) × (13.3-) 15.4-16.8 µm, 4- and occasionally 2-spored, thin-walled; no clamps seen. UNIVERSAL VEIL: In volval sac: dominated by inflated cells—globose to subglobose to 51.8 × 45.5 µm, clavate to broadly clavate to 56.0 × 38.5 µm, terminal, singly or in short chains, thick-walled; frequently branching, filamentous, undifferentiated hyphae plentiful, 3.8-12.6 µm diam, many segments (particularly near-terminal segments) thick-walled; oleiferous hyphae present to 4.9 µm diam; no clamps seen. In possible "ochraceous flake" on surface of volval sac: hyphae and inflated cells both plentiful; some hyphae coiling; surface somewhat gelatinizing; scattered small patches of parallel hyphae a few hyphal diams thick, slightly gelatinizing to gelatinizing, mutually parallel and possibly longitudinally arranged; oleiferous hyphae to 7.0 µm; otherwise little difference from remainder of universal veil. STIPE CONTEXT: acrophysalidic; branching, filamentous, undifferentiated hyphae 2.1-13.3 µm diam dominating, many appearing thick-walled; acrophysalides clavate to narrowly clavate, thick-walled, to 220 × 55 µm; branching, oleiferous hyphae plentiful, 1.4-4.5 µm diam; no clamps seen. All tissues pale yellowish in ammonium hydroxide.

BASIDIOSPORES: [80 from 4 specimens] (8.0-) 9.8-14.0 (-14.3) × (7.0-) 9.1-13.3 (-13.6) µm, (average length per collection = 10.7-12.2 µm; average length (overall) = 11.3 µm; average width per collection = 10.3-11.4 µm; average width (overall) = 10.7 µm; Q = 1.0-1.12 (-1.24); average Q per collection = 1.04-1.07; average Q (overall) = 1.06), inamyloid, thin-walled, hyaline, globose to subglobose, rarely broadly ellipsoid, frequently adaxially flattened, sometimes swollen slightly at one end; contents guttulate; apiculus sublateral, truncate conic, can be rather large relative to spore size; white in deposit.

Collections examined: **GREENLAND**, Equaluit fjord 25 km from Paamiut, 29.viii.1985 T. Borgen TB.85.133 (TBor), 24.viii.1986 T. Borgen TB.86.257 (TBor), Qunqua Valley, 27.vii. thru 23.viii.1983 Knudsen, Borgen & Petersen 462 (L, part of paratype).

The following are characters of *A. mortenii* distinguishing it from *A. sinicoflava*:

— The occasional presence of small, ochraceous flakes on the exterior, upper surface of the volval sac.

— Thick-walled, inflated cells throughout the context of pileus and stipe, lamella trama, and the universal veil. These are easily seen if the tissue is stained with Congo Red and viewed with an oil immersion lens at 1000×. The wall thickness is 1.0-1.2 µm.

— Many thick-walled hyphae throughout the basidiocarp. Often the cell walls of such hyphae are not as thick as the walls of the inflated cells.

— A cellular subhymenium.

— Shorter acrophysalides in the stipe context.

— A thicker pileipellis.

— Generally narrower and possibly more plentiful, oleiferous hyphae.

— Basidia slightly longer.

— Spores slightly larger.

Amanita submembranacea (Bon) Gröger. 1979. *Boletus* 3(2): 27.

≡*Amanitopsis submembranacea* Bon. 1975. *Bull. Mem. Soc. Linn. Lyon* 44(6): 176.

PILEIPELLIS: approximately 230 µm thick; radially arranged, interwoven, gelatinizing, undifferentiated, filamentous, branching hyphae 1.7-9.4 µm diam; oleiferous hyphae present, 4.9-8.4 µm diam. PILEUS CONTEXT: undifferentiated, filamentous, branching hyphae 4.5-14.0 µm diam with inflated branching cells and hyphal tips to 29.0 µm diam; oleiferous hyphae present, 6.3-9.1 µm diam; inflated cells subglobose to globose, to 60 × 60 µm, ovoid, elongate, clavate to irregular, to 175 × 55 µm. LAMELLA TRAMA: bilateral; dominated by inflated cells which are elongate, clavate, ovoid, subglobose, irregular, occasionally in chains, to 118 × 41 µm; undifferentiated, filamentous, branching hyphae 4.2-9.1 µm diam, seen to be dominating near subhymenium when tissue is crushed; branching oleiferous hyphae plentiful, 2.8-7.0 µm diam, extending into hymenium; subcoralloid elements extending into hymenium. SUBHYMENIUM: cellular (single cells at the termini of hyphae) to undifferentiated hyphae to "subirregular (slightly coralloid?)" (C. Bas' notes in L). BASIDIA: (39-) 50-84 (-92) × (13.5-) 14-18.5 (-20) µm,[5] 4-spored, thin-walled; "rarely clamped" (C. Bas' notes in L). UNIVERSAL VEIL: On stipe base: an outer layer, about 3 hyphal diams thick of longitudinally oriented, parallel hyphae; plentiful inflated cells ovoid to globose to subglobose, to 72.1 × 66.5 µm; oleiferous hyphae present, 4.9-5.6 µm diam; and interwoven, undifferentiated, filamentous, branching hyphae 2.8-8.4 µm diam; inner surface gelatinizing. On pileus: similar. STIPE CONTEXT: acrophysalidic; dominated by acrophysalides to 310 × 60 µm; undifferentiated, filamentous, branching hyphae 3.5-8.0 µm diam; branching, largely longitudinally oriented, oleiferous hyphae 4.2-15.4 µm diam, common to locally plentiful; no clamps seen. All tissues pale yellowish in ammonium hydroxide.

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[5] The basidia from the type fragments at L (Bon 740917) represent the lower end of the distribution range; however, basidia from the other Bon collection at L (740920) were the largest observed.

BASIDIOSPORES: [146 from 8 specimens] (8.3-) 9.8-12.6 (-13.6) × (7.3-) 8.4-11.6 (-13.4) µm, (average length per specimen = (9.8-) 10.3-11.5 µm; average length (overall) = 10.8 µm; average width per specimen = (9.2-) 9.6-10.9 µm; average width (overall) = 10.1 µm; Q = 1.0-1.14 (-1.26); average Q per collection = 1.06-1.10; average Q (overall) = 1.07), inamyloid, thin-walled, hyaline, globose to subglobose, slightly adaxially flattened; contents guttulate; apiculus rather large, subcylindric to cylindric; white in deposit.

Collections examined: **AUSTRIA**, Tirol, Pitztal, Tiefental, 2.ix.1962 M. Moser 62/16 (IB), near Arzleralm ober Piösmes, 26.vii.1967 M. Moser 67/21 (IB); **FRANCE**, Haute Loire, Fontanet near Le Puy, 17.ix.1974 Bon 740917 (holotype, fragment in L), Mt. Mezenc, 20.ix.1974 Bon 740920 (L); **ITALY**, Trentino, Valsugana, Cinque Valli btwn. Roncegno & Vetriolo Terme, 3.ix.1987 Bas 9144 (L); **POLAND**, Kielce Prov., near Kielce, Willkovska valley in Swietokrzyskie mountains, 10.ix.1966 Bas 4746 (L); **SWITZERLAND**, Graubünden Canton, St. Moritz, 26.viii.1976 C. Bas 7021 (L), Schwyz, Sattel, Mosselberg, 9.ix.1976 G. & F. Tjallingii s.n. (L).

Judging from the specimens of *A. submembranacea* and accompanying transparencies in L, from the pileus dimensions and illustrations of *submembranacea* in (Bon, 1975: 176) and (Merlo & Traverso, 1983: 48), and from a collection with accompanying watercolor painting in IB (Moser 62/16), *A. submembranacea* produces a larger, more robust basidiocarp than does *A. sinicoflava*. Judging from exsiccatae in L and IB, *A. submembranacea* is much more likely to have a large patch of universal veil on its pileus than is *A. sinicoflava*. *Amanita submembranacea* (including "*A. subalpina*" Moser ined. (C. Bas, private communication)) is known only from coniferous woods on acid soils (Bon, 1975 and Moser, 1983).

In the volva of *A. submembranacea*, a broken, thin fibrillose-felted to submembranous outer layer is visible to the naked eye in many, well-preserved exsiccatae; remnants of the outer layer superimposed on the grayish unbroken inner volval layer may give the appearance of bits of flaking paint on old canvas. This character is completely absent in *A. sinicoflava*.

The spores of *A. submembranacea* are about the same size as, or slightly larger than, those found in *A. sinicoflava*. Spores of "*A. subalpina*" may be as large as 12-17 × 12-15 µm (Moser, 1983).

In addition, the following characters of *A. submembranacea* serve to distinguish it from *A. sinicoflava*:

— A cellular subhymenium.

— Shorter acrophysalides in the stipe context.

— A thicker pileipellis.

— Slightly longer basidia—in most specimens.

Amanita mortenii and *A. submembranacea* seem to be more closely related to each other than either is to *A. sinicoflava*. The major differences between them lie in the thick-walled cells of *A. mortenii*, which are slightly smaller than the corresponding thin-walled elements in *A. submembranacea*, and in the slightly larger spores of the former. Thick-walled cells have not been evaluated as a character throughout *Amanita*.[6] Knudsen & Borgen (1987) have used them for the first time as a character on which to establish a species concept.

In addition to the two taxa examined in detail above, there are a number of others which require mention because of some similarity to *A. sinicoflava*. The fungus illustrated as *A. strangulata* (Fries) Quélet by Merlo & Traverso (1983) has pileus coloration which is similar to, although paler than, that of *A. sinicoflava*. This European entity is distinguishable—at least by its larger spores (12-14 µm diam) and its smaller ratio of striation length to pileus radius.

The literature contains five other taxa in *Amanita* section *Vaginatae* with globose cells dominant in the universal veil and globose to subglobose spores. The universal veil in *A. sinicoflava* is similar to that of *A. ceciliae* of Europe (Corner & Bas, 1962 and Bas, 1984) and "*A. inaurata*" ss. Pk. of North America (description and discussion under *A. ceciliae* (Jenkins, 1986)). However, *A. sinicoflava* can be distinguished from either of these fungi by its pileus with olive tones, a smaller habit, and a commonly more robust universal veil frequently appearing as a constricted, saccate volva on the stipe base rather than as warts on the pileus which latter occurrence is more common in *A. ceciliae* and "*A. inaurata*" ss. Pk. The acrophysalides in the stipe of *A. sinicoflava* are up to twice as long as those of "*A. inaurata*" ss. Pk. (Jenkins, 1986). *Amanita cinctipes* Corner & Bas (Corner & Bas, 1962) of southeast Asia has a universal veil similar to that of *A. ceciliae*, but sometimes appearing in small pyramidal warts on the pileus; its spores are reported to be smaller than those found in *A. sinicoflava*; *A. cinctipes* lacks an umbo; and its coloration is said to tend to grayish tones. *Amanita craseoderma* Bas (Bas, 1978) of the Amazon region has even smaller spores than *A. cinctipes*, a "very dark brownish grey" pileus, and considerably narrower basidia than *A. sinicoflava*. The pileus of *A. craseoderma* lacks an umbo. *Amanita groenlandica* Bas ex Knudsen & Borgen has a larger pileus than *A. sinicoflava* with shorter (0.1-0.2R) marginal striations, no umbo, and frequently a patch or patches of universal veil. Knudsen & Borgen (1987) also describe *A. groenlandica* as "relatively short-stemmed" and robust—another difference.

Three additional Western Hemisphere species of *Amanita* exhibit a universal veil somewhat similar to that in *A. sinicoflava*—*A. antillana* Dennis of Trinidad (Dennis, 1952 and Bas, 1978), *A. coacta* Bas of the Amazon region (Bas, 1978), and *A. constricta* Thiers & Ammirati of California (Thiers & Ammirati, 1982). However, all exhibit an average Q greater than that (1.06) seen in *A. sinicoflava*—1.2 in *A. antillana*, 1.3 in *A. coacta*, and approximately 1.2 in *A. constricta*. The closest of these to *A. sinicoflava* is the last named which can have a submembranous universal veil; however, *A. constricta* is further distinguished from *A. sinicoflava* by a gray-brown to hair brown pileus, red staining in the universal veil when moist, and striations that represent only about 0.2R (Thiers & Ammirati, 1982).

It should be noted that the collections of *A. sinicoflava* made in the Coastal Plain ecological region (those from New Jersey's Mercer and Monmouth counties) had, with but one exception, smaller spores than all other collections examined. I conjecture that this is due, at least in part, to the rapid loss of surface moisture due to the soil of the Monmouth County collection region being entirely composed of sand. Unlike many radicating species of *Amanita* section *Lepidella* which occur in the Coastal Plain, basidiocarps of *A. sinicoflava* sit high in the soil—even to the extent of the volval sac being almost entirely above ground. This fact can be confirmed even in exsiccatae because one finds fragments of leaves (and almost no sand at all) attached to the surface of the very bottom of the stipe.

In the field in eastern North America, *A. sinicoflava* is distinguished from taxa close to *A. vaginata* (Bull. per Fr.) Vittadini and *A. fulva* by pileus coloration. These taxa do not exhibit the graying, submembranous to membranous volval sac of *A. sinicoflava*. The prominent orange-rusty stains frequently found on the volva of *A. fulva* do not occur in *A. sinicoflava*.

Amanita sinicoflava is the entity to which I have applied the name "species 2" in recent correspondence.

ACKNOWLEDGMENTS

I thank all my correspondents who supplied material of *A. sinicoflava*. I am grateful to Mr. N. Macdonald, Princeton, New Jersey, who prepared the illustrations. I had the benefit of several discussions on this article with Dr. D. T. Jenkins, University of Alabama, Birmingham. Mr. T. Borgen, Paamiut, Greenland, answered questions regarding *A. mortenii* and generously gave me portions of two of his collections of that species. I especially thank Dr. C. Bas, Rijksherbarium, Leiden, The Netherlands, for his reviewing this paper, for several discussions of the taxa described or mentioned in this paper, for his permission to examine the collections of *A. submembranacea* in his laboratory, and for his gift of a portion of Bas 7021 and duplicate transparencies.

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6. It is not clear how common cell wall thickening may be in *Amanita*. My examination of the literature for references to thickened walls in *Amanita* cells is incomplete; however, I found no reference to thick-walled elements in North American species (Jenkins, 1986). Bas (1969) depicts no such elements in section *Lepidella*. Reid (1980) depicts "thin but distinct" walls in hyphae of volval remains on the pilei of both Australian and English collections of *A. phalloides* (Fr.) Link in Wildenow (section *Phalloideae*) and of the Australian species *A. peltigera* Reid (section *Phalloideae* (or *Amidella*?)); Reid does not describe the cell walls in inflated elements. In the volval tissue of a New Jersey collection of *A. phalloides* (Tulloss 10-29-83-A), with the possible exception of a few narrow hyphae, all elements had thickened walls; the acrophysalides of the stipe context had cell walls to 1.2 μm thick.

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PROLIXANDROMYCES TRIANDRUS SP. NOV. (LABOULBENIALES) FROM SPAIN

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SUMMARY

A new species of Prolixandromyces (Laboulbeniales, Ascomycotina), parasitic on Velia caprai (Hemiptera, Veliidae) is described and illustrated: P.triandrus. This is the first european species of a genus that was only known from Central America.

INTRODUCTION

The genus Prolixandromyces was established by Benjamin (1970) by the description of two species: P. veliae and P. corniculatus, both on species of Velia from Mexico. Later, this same author (Benjamin, 1981) described three more species: P. lingulatus, P. rhinoceralis and P. tenuis, on the same host genus, from Nicaragua and Costa Rica; he also added some new data and localities (El Salvador, Nicaragua) for the two first species. The species here proposed, named Prolixandromyces triandrus is the only one in the genus collected outside of Central America. Its presence in Europe widens considerably the area of distribution for the genus. Like the other five species, P. triandrus parasitizes a hemipteran of the family Veliidae, Velia caprai Tamanini, a semiaquatic bug which is very common in areas of the Iberian Peninsula flooded with fresh waters.

The genus Prolixandromyces (Laboulbenieae, Stigmatomycetinae) is characterized by its three-celled receptacle (three superposed cells), a primary appendage that includes the antheridia, with long and sinuate discharge tubes, and the perithecium with apical outgrowths.

DESCRIPTION

Prolixandromyces triandrus Santamaría, sp. nov.
(figs. 1-9)

Coloratio generalis aurantiaca diluta. Receptaculum triquetrum, ab oris directis sive leviter sinuatis. Cellula I angusta, ter sive quater longior quam amplior. Cellula II angustior quam prima, duplo sive ter longior quam amplior. Cellula II angustior quam prima, duplo sive ter longior quam amplior. Cellula III subtriquetra leviter longior quam amplior. Appendix primaria a quattuor cellulis sterilibus et tribus antheridiis formata. Cellula basalis triqueter, a subbasali cellula separata saepto fortiter obliquo. Cellula subbasalis in forma parallelogrammi, a superiore parte appendicis separata saepto fortiter obliquo. Tria antheridia a duabus cellulis relictis sterilibus interposita. Antheridia cum longis et curvatis tubis. Relictus apex sporae perspicius et in inverso antheridio medio collocatus. Perithecium directum. Cellula VI robusta, constricta prope basem. Cellula VII subtriquetra. Cellulae basales perithecii (m, n, n') longae. Secundus ordo horizontalis cellularum parietalium angustus, anulum clare notatum formans. Cellula apicalis ordinis verticalis cellularum parietalium (a cellula m surrectarum) cum excrescentia longa, directa, apice truncato, et duabus parvis expansionibus obtusis in infra directis.

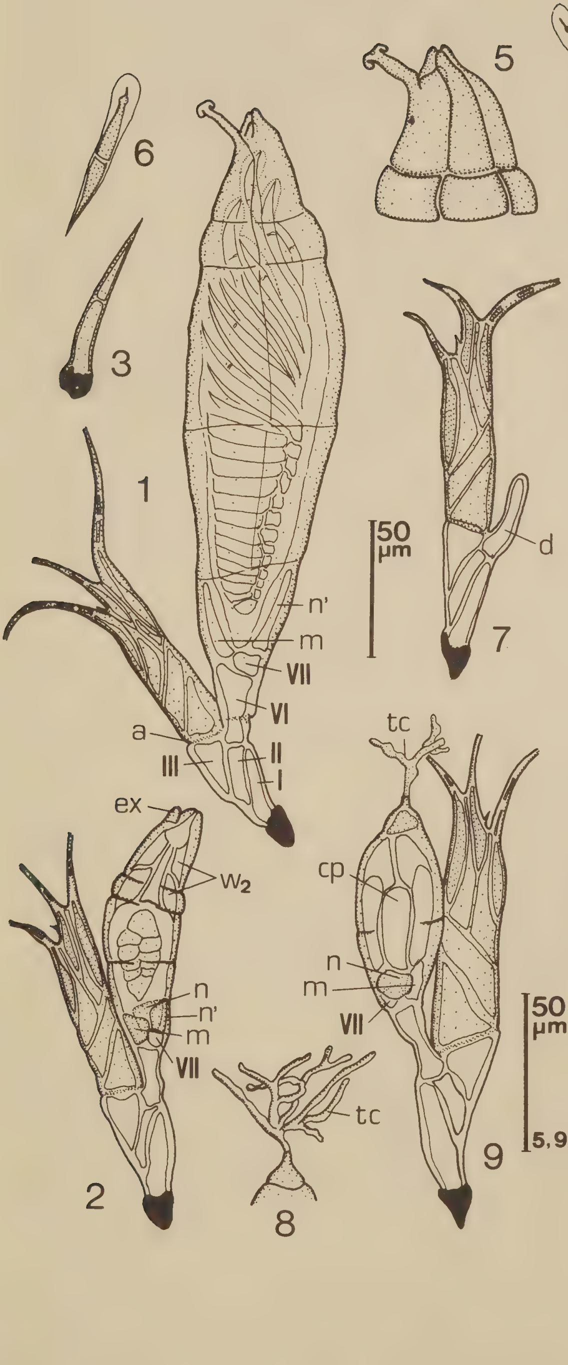
Longitudo receptaculi: 42-55 µm. Longitudo appendicis primariae: 85-125 µm. Venter antheridii: 20-25 µm. Tubus antheridii: 30-65 µm. Longitudo cellulae VI: 30-62 µm. Perithecium: 150-280 µm x 41-70 µm.Excrescentia perithecii: 19-28 µm. Ascosporae:50-62 µm. Totus fungus 220-400 µm longus.

Holotypus: SS743. BCB-Mycotheca. In locis Gerundae (Catalonia, Hispania).

Overall color, pale orange, more intense in the primary appendage and the perithecium.

Receptacle: Pyramidal, with even or slighly sinuate surface (42-55 µm long). Basal cell (I) narrow, 3-4 times as long as broad. Suprabasal cell (II) narrower than I, 2-3 times as long as broad. Cell III subtriangular in lateral view, slightly longer than wide. The suprabasal cell gives rise to the perithecium and its basal cells (cell VI included). The three cells of the receptacle are usually in contact with the stalk cell (VI) of the perithecium, although sometimes the basal cell (I) is not in contact. The primary septum (located over cell III) is marked by a constriction and is not deeply pigmented.

Figures 1-9. *Prolixandromyces triandrus*. 1. Mature isotype (SS739a). General arrangement of cells. a, primary septum. 2. Immature specimen after fertilization. Perithecial outgrowth starting to develop (ex). Wall cells of internal tier (w_2). (SS739b, isotype). 3. Ascospore just implanted on the host tegument. 4. Mature individual (SS743, holotype). 5. Apex of the perithecium showing the arrangement of apical wall cells. 6. Ascospore. 7. Early stage of development. The perithecial initial cell (d) derived from suprabasal cell (II) (SS748b). 8. Branched trichogyne (SS768g). 9. Immature specimen before fertilization. tc, trichogyne. cp, carpogonial cell. (SS768g).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Appendage: Formed by four sterile cells and three antheridia 85-125 µm long. Basal cell triangular in lateral view, separated from the suprabasal cell by a strongly oblique septum. Suprabasal cell with parallel walls, separated from the three antheridia and the other two sterile cells by an oblique septum. The three antheridia are separated from each other by two long and slender sterile cells. Antheridia long and slender, with discharge tubes longer (25-65 µm) than the venter (20-25 µm). The rest of the spore apex (spine-like) remains on the dorsal side of the central antheridium.

Perithecium: Stalk cell (VI) 30-62 µm long, with a small constriction near the base. Secondary stalk cell (VII) subtriangular. Basal cells (m, n, n') long in mature specimens. Body of perithecium straight, 150-280 µm long by 41-70 µm wide. In each vertical row of outer wall cells of the perithecium there are 4 cells of unequal height. The subapical horizontal row of wall cells very short, protruding externally in an even curve beyond the surface of the cells above and below. The apical cell of the posterolateral wall cell row, borne on cell m (that also shows the trichogyne stump), forms an elongate subterminal outgrowth (19-28 µm) with a truncate apex and two small rounded expansions pointing downwards. The trichogyne is branched. The ascospores (50-60 µm long) are hyaline, having a lower cell slightly longer (30-35 µm) than the upper one (21-27 µm).

Total length from base of the foot to the apex of perithecium, between 220 µm and 400 µm.

Etymology.- From tri-, three, and -andrus, male, referring to the presence of three antheridia.

Holotype.- SPAIN: Torrente de Can Plana, Riells i Viabrea (Gerona, Catalunya), 9-VIII-87, UTM: 31TDG6120. On legs of Velia caprai Tamanini (Hemiptera, Veliidae); BCB-Mycotheca, SS743.

Isotypes.- SPAIN: Ibidem. On legs, antennae and head of Velia caprai Tamanini; slides SS739a, SS739b, SS747a, SS747b, SS747c, SS748a, SS748b, SS748c, SS748d, SS748e, SS748f, SS748g, SS748h, SS748i, SS749; BCB-Mycotheca.

All slides of the holotype and isotypes are in the herbarium of the "Departament de Biologia Animal, Vegetal i Ecologia" of the "Universitat Autònoma de Barcelona" (BCB-Mycotheca), except slides SS747c and SS748h sent respectively to Dr. I.I. Tavares and Dr. J. Balazuc.

DISCUSSION

The first European species of Prolixandromyces differs in a number of ways from the previously known species: (1) the perithecial outgrowth is subapical instead of terminal, in addition to having a particularly complex structure, (2) three functional antheridia are present, instead of two, as in the other species, and the antheridial necks are proportionally much shorter, (3) there are four sterile cells in the primary appendage, as opposed to three in the rest of species, two of these cells function as stalk cells of the antheridia, the extra antheridium therefore has an extra stalk cell, (4) the antheridial stalk cells are longer and different in form, and (5) the apices of the uppermost wall cells do not extend upward very much.

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A NEW SPECIES OF PHIALOPHORA

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ABSTRACT

A new species of *Phialophora, P. intermedia* Iwatsu, Udagawa et Toyazaki, is described and illustrated from a collection made on house-dust in Japan.

Recently there has been increasing interest in the occurrence of specialized saprophytic fungi, such as black yeasts, in foods or in indoor environments and their potential hazards to human health (Kazanas, 1986;Nishimura et al., 1987; Iwatsu et al., 1988). This was prompted primarily by concern over the infectivity of some potentially opportunistic invaders (e.g. *Exophiala dermatitidis* (Kano) de Hoog) for a mammalian host by oral intubation (Kazanas, 1986). During a public health survey of fungal populations in household dust, one of the authors (N. T.) isolated a hyphomycete belonging to the genus *Phialophora* Medlar. A comparison with known species of *Phialophora* and allied genera indicates that the fungus represents an undescribed taxon. Therefore, it is described as a new species herein.

TAXONOMIC PART

Phialophora intermedia Iwatsu, Udagawa et Toyazaki, sp.nov. (Figs. 1, 2)

Coloniae in agaro "potato-dextrose" satis crescentes, post 14 dies ad temperaturam 27°C 3.4-3.8 cm diametro, floccosae, griseo-olivaceae; reversum atriolivaceum. Exsudatum nullum et odor absens. Mycelium partim immersum vel partim superficiale, ex hyphis ramosis, subhyalinis vel pallide olivaceis, septatis, laevibus 1.5-2.5 µm crassis compositum. Conidiophora micronemata vel semi-macronemata, mononemata, ex hyphis oriunda, simplicia, subhyalina vel pallide olivacea, laevia. Cellulae conidiogenae monophialidicae, laterales vel terminales, ex hyphis statim et singulatum oriundae, vel ex conidiophoris singulatim vel diverse oriundae, discretae, rectae vel modice sinuosae, subcylindricae, ampulliformes vel lageniformes, subhyalinae vel pallide olivaceae, laeves, 6-15 x 2-3.5 (mediae 10.8 x 2.4) µm; collare plerumque inconspicuum sed interdum conspicuum, si adsunt, cupulatum, 1 µm altum, 1.5-2.5 µm crassum. Conidia unicellularia, plerumque ellipsoidea, minus plerumque subglobosa, subcylindrica vel reniformia, hyalina vel pallide olivacea, laevia, 4-6 x 1.5-2.5(-3.5) (mediae 4.7 x 2.2) µm, in massa mucida aggregata vel nonnumquam in catenis fragilibus cohaerentia. Chlamydosporae adsunt.

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Holotypus: cultura NHL 2979, ex materia pulveratus in domo, Suita, Osaka, in Japonia, in 5.iv.1984, a N.Toyazaki, isolata. In collectione fungorum "National Institute of Hygienic Sciences (NHL), Tokyo, Japan".

Etymology: Lat. *intermedia,* referring to its intermediate characteristics between sect. *Phialophora* and sect. *Catenulata.*

Colonies on potato-dextrose agar growing moderately, attaining a diameter of 3.4-3.8 cm in 14 days at 27°C, floccose, Gray Olivaceous (Rayner, 1970); reverse Dark Olivaceous (Rayner). Exudate and odor absent.

Mycelium partly immersed or partly superficial, composed of branched, subhyaline to pale olivaceous, septate, smooth, 1.5-2.5 µm wide hyphae. Conidiophores micronematous to semi-macronematous, mononematous, arising from the hyphae, simple, subhyaline to pale olivaceous, smooth. Conidiogenous cells monophialidic, lateral or terminal, borne directly and singly on the hyphae, or singly or as divergent forks on the conidiophores, discrete, straight or more or less sinuate, subcylindrical, ampulliform or lageniform, subhyaline to pale olivaceous, smooth, 6-15 x 2-3.5 (av. 10.8 x 2.4) µm; collarettes usually inconspicuous but sometimes conspicuous, when present cupulate, 1 µm in depth and 1.5-2.5 µm in width. Conidia one-celled, predominantly ellipsoidal, less commonly subglobose, subcylindrical or reniform, hyaline to pale olivaceous, smooth, 4-6 x 1.5-2.5 (-3.5) (av. 4.7 x 2.2) µm, aggregated in a slimy mass or

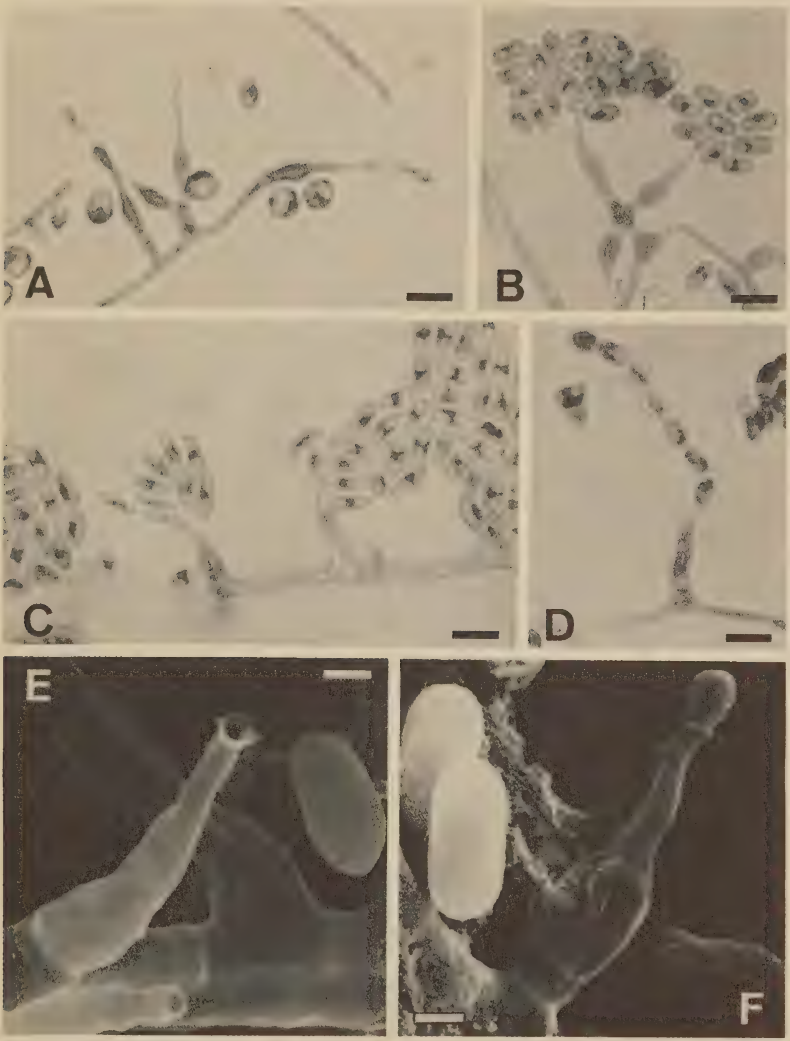

Fig. 1. *Phialophora intermedia.* Phialides and conidia.
A-D) Light microscopic photographs. Bar=5 µm.
E,F) Scanning electron microscopic photographs. Bar=1 µm.
A, E) NHL 2979. B, C, D, F) NHL 2978.

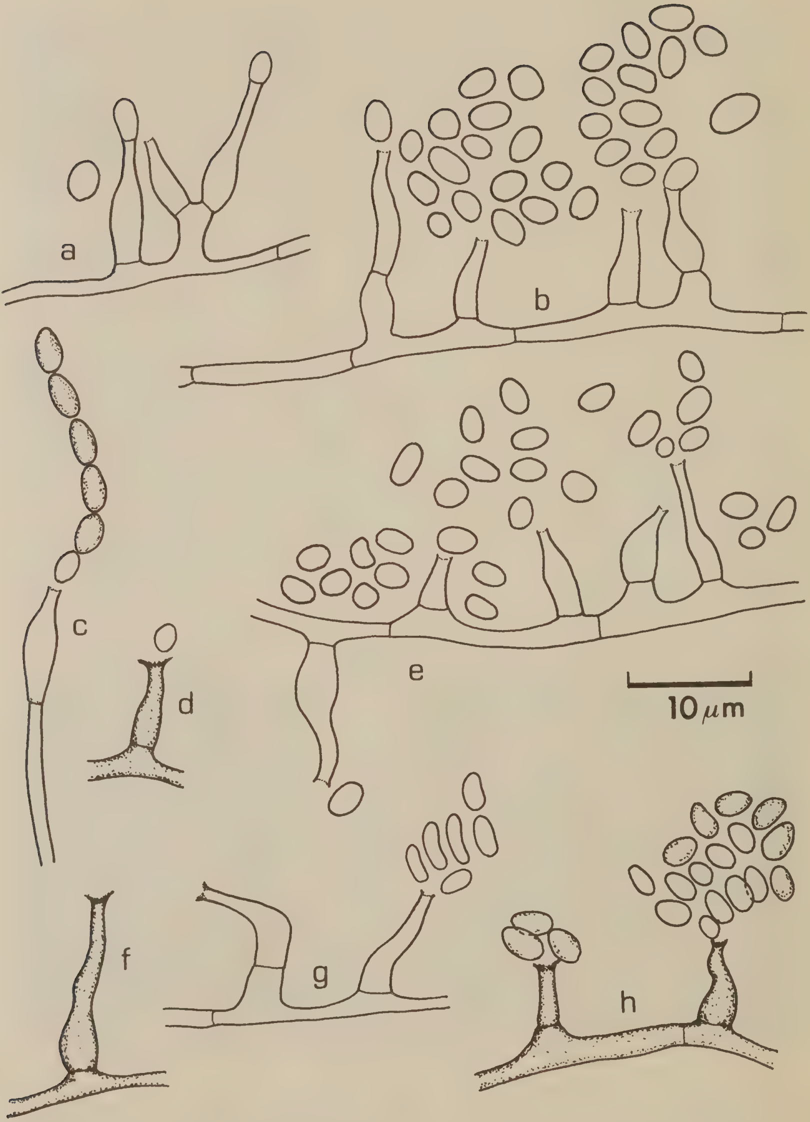
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Fig. 2. *Phialophora intermedia.* Phialides and conidia. a-e) NHL 2979. f-h) NHL 2978.

sometimes forming fragile chains. Chlamydospores present.

Growth is slower at 37°C than at 27°C.

Specimens examined: NHL 2979 (holotype) isolated from house-dust in Senrigaoka, Suita City, Osaka Pref., Japan, April 5, 1984, on DG-18 agar by N. Toyazaki; NHL 2978, isolated from dried salted food (powder of salmon and "wakame" (*Undaria pinnatifida* (Harvey) Suringar)), in Nagoya City, Aichi Pref., Japan, September, 1984, by H. Tsubouchi. The specimens studied and living cultures derived from them are preserved at the National Institute of Hygienic Sciences, Tokyo, Japan.

DISCUSSION

In 1976, Gams and Holubová-Jechová introduced a new section, sect. *Catenulata* W. Gams, in the genus *Phialophora* for species producing catenate, cuneate or dacryoid conidia. For the remaining species having ellipsoidal or allantoid conidia, which are aggregated in a slimy mass, sect. *Phialophora* was reserved. It is noteworthy that the conidia in *P. intermedia* are usually aggregated in a slimy mass at the apex of the phialides, but sometimes form chains. *Phialophora intermedia* may be a fungus which provides a link between the two sections.

Several morphological features and cultural characteristics, as well as ability to grow at 37°C, serve to distinguish *P. intermedia* from its nearest relatives. *Phialophora intermedia* is somewhat similar to *P. fastigiata* (Lagerb. et Melin) Conant, *P. melinii* (Nannf.) Conant and *P. malorum* (Kidd et Beaumont) McColloch, but in these species the phialides often occur in verticillate clusters (Schol-Schwarz, 1970). Furthermore, the margin of the colonies in these species is colorless, and they have no ability to grow at 37°C. *Phialophora parasitica* Ajello, Georg et Wang differs from *P. intermedia* in predominantly producing allantoid conidia (de Hoog, 1983). *Phialophora intermedia* somewhat resembles *P. lagerbergii* (Melin et Nannf.) Conant and *P. repens* (Davidson) Conant, but these species are more rapid-growing and produce predominantly allantoid conidia (Schol-Schwarz, 1970). *Phialophora bubakii* (Laxa) Schol-Schwarz is also similar to the authors' fungus, but produces predominantly allantoid conidia in young cultures (Schol-Schwarz, 1970; Morgan-Jones, 1978). *Lecythophora hoffmannii* (Beyma) Gams et McGinnis and *L. lignicola* Nannf. differ from *P. intermedia* in producing colonies with a tinge of orange to pink and in more commonly producing adelophialides rather than discrete phialides (de Hoog, 1983; Gams and McGinnis, 1983)

Some members of the genus *Phialophora,* such as *P. verrucosa* Medlar, *P. richardsiae* (Nannf.) Conant, *P. parasitica, P. repens,* and *P. cyanescens* de Vries, de Hoog et de Bruyn, are known as human pathogens (de Hoog, 1983; de Vries et al., 1984), most of which have ability to grow at 37°C. *Phialophora intermedia* is also able to grow at 37°C. The ability of a fungus to grow at 37°C is thought to be an useful criterion in separating human-pathogenic species from nonpathogens (Wang and Brownell, 1967). If *P. intermedia* has potential pathogenicity, this fungus might possibly be isolated as an opportunistic pathogen from man in the future.

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CALCEOMYCES, A NEW GENUS OF THE XYLARIACEAE WITH SHOE-SHAPED ASCOSPORES

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SUMMARY

A new genus and species of the Xylariaceae, *Calceomyces lacunosus,* is described and illustrated from an isolate obtained from activated sludge in Japan. It is characterized by non-stromatic perithecia and shoe-shaped ascospores with ridges forming a coarse reticulum. The associated anamorph is referrable to *Nodulisporium*.

As saprophytes or weak parasites, most members of the family Xylariaceae are collected from decaying wood, roots and old stumps of Angiosperms. Even coprophilous representatives of the family are nourished primarily by decayed Angiosperms and are considered to be specialized Angiosperm saprophytes (Rogers, 1979). Isolations of *Geniculosporium* and *Nodulisporium* from decayed Angiosperms also show their association with xylariaceous teleomorphs in soil. However, evidence is still incomplete because there is only one report of an isolate linked to the teleomorphic state, *Hypoxylon serpens* (Pers.) Kickx, in culture (Barron, 1968), or few records and collections of terricolous species in the Xylariaceae.

During microbiological studies on the environmental pollution in the Nagasaki Prefecture, southwestern Japan, a remarkable ascomycete was encountered colonizing a plate of activated sludge from the Nishiyama water reservoir. The ascospores are distinctive in being composed of a wooden shoe-shaped dark cell with a few ridges forming a very coarse reticulum. The anamorphic state referrable to the form-genus *Nodulisporium* which developed on the external surface of the perithecia was also observed. This ascomycetous fungus is characterized by dark non-stromatic perithecia, cylindric asci with an amyloid "apical ring", dark-colored inequilateral ascospores having a longitudinal germ slit and the *Nodulisporium* anamorph. Members of the family Xylariaceae typically form their perithecia embedded in a true stroma composed entirely of fungal tissue with only the perithecial ostioles protruding (Alexopoulos and Mims, 1979). Recent studies have indicated that a number of genera from several families, with perithecia borne singly, are closely related to the stromatic Xylariaceae. For example, *Ascotricha* species are probably more closely related to species of the stromatic Xylariaceae than to other members of the Chaetomiaceae, regardless of whether the perithecia are non-stromatic or borne on a subiculum (Khan and Cain, 1977). Besides its non-stromatic perithecia, the other features of this fungus are typical of the Xylariaceae and, since no other xylariaceous genus is known with this combination of characteristics, it is described here as a new genus of the Xylariaceae.

Calceomyces Udagawa et Ueda, gen.nov.

Perithecia dispersa, superficialia vel semi-immersa, non-stromatica, pyriformia vel ovoidea, atribrunnea vel nigra; peridium membranaceum, multi-stratosum. Asci unitunicati, cylindracei, annulo apicali distincti et amyloidei, in fasciculo parallelo dispositi. Paraphyses numerosae, filiformes. Ascosporae unicellulares, atribrunneae, calceiformes, reticulatae cum cristis irregularibus et depressionibus non profundis a superficie visis sed complanatae et leves a solo visis, strato gelatinoso circumdatae, fissura germinali paratae. Status anamorphus ad *Nodulisporium* pertinens.

Typus generis: *Calceomyces lacunosus* Udagawa et Ueda.

Etymology: *calceo* =to shoe and *myces* =fungus, referring to the ascospore shape.

Perithecia scattered, superficial to sem-immersed, non-stromatic, pyriform to ovoid, dark brown to black; peridium membranaceous, several-layered, composed of an outer dark brown layer and inner hyaline layers. Asci unitunicate, cylindrical, provided with a distinct ring in the apex, amyloid, arranged in a parallel fascicle. Paraphyses numerous, filiform. Ascospores one-celled, dark brown, shoe-shaped, trapezoid in side view, reticulate with irregular ridges and shallow depressions in face view but flattened and smooth in reverse view, each surrounded by a gelatinous sheath. Germ slit extending full length of the

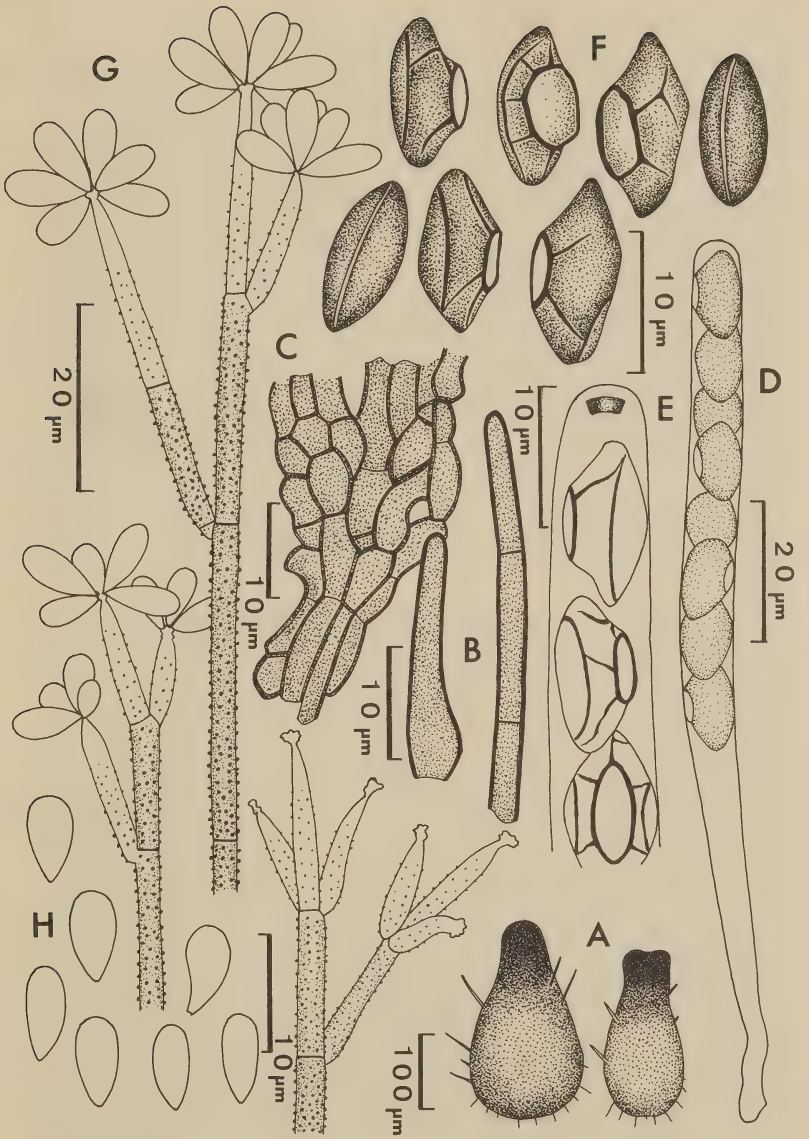
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Fig. 1. *Calceomyces lacunosus,* NHL 2983.
A. Perithecia. B. Hairs. C. Peridium. D. Ascus.
E. Apical portion of the ascus. F. Ascospores.
G. Conidiogenous cells and conidia. H. Conidia.

spore. Anamorphic state: *Nodulisporium*.

Calceomyces lacunosus Udagawa et Ueda, sp.nov.
(Figs. 1-5)
Stat. Anam. *Nodulisporium*.

Perithecia dispersa, superficialia vel semi-immersa, non-stromatica, pyriformia vel late ovoidea, 210-310 x 105-170 µm, atribrunnea vel nigra, circum basim colli pilis paucis brevibus tecta; pili brunnei, stricti, parce septati, leves, 30-65 x 4-5 µm; collum conicum vel brevicylindraceum, 80-130 x 65-95 µm, atribrunneum; peridium membranaceum, ex "textura intricata" vel "textura angularis" compositum, 3-5-stratosum. Asci 8-spori, cylindracei, 90-125 x 8-9 µm, annulo apicali parvo iodo caerulescentes, inferne in stipitem brevem vel satis longum attenuati; paraphyses numerosae, hyalinae, septatae, filiformes vel aliquanto inflatae. Ascosporae uniseriatae, atribrunneae, calceiformes, (9.5-)10-14 x 5-6 x 6-6.5 µm, trapezoideae a latere visis et fusiformes vel ellipsoideae a vertice visis, reticulatae cum cristis irregularibus et depressionibus non profundis a superficie visis, complanatae et leves a solo visis, strato gelatinoso circumdatae, fissura germinali paratae.

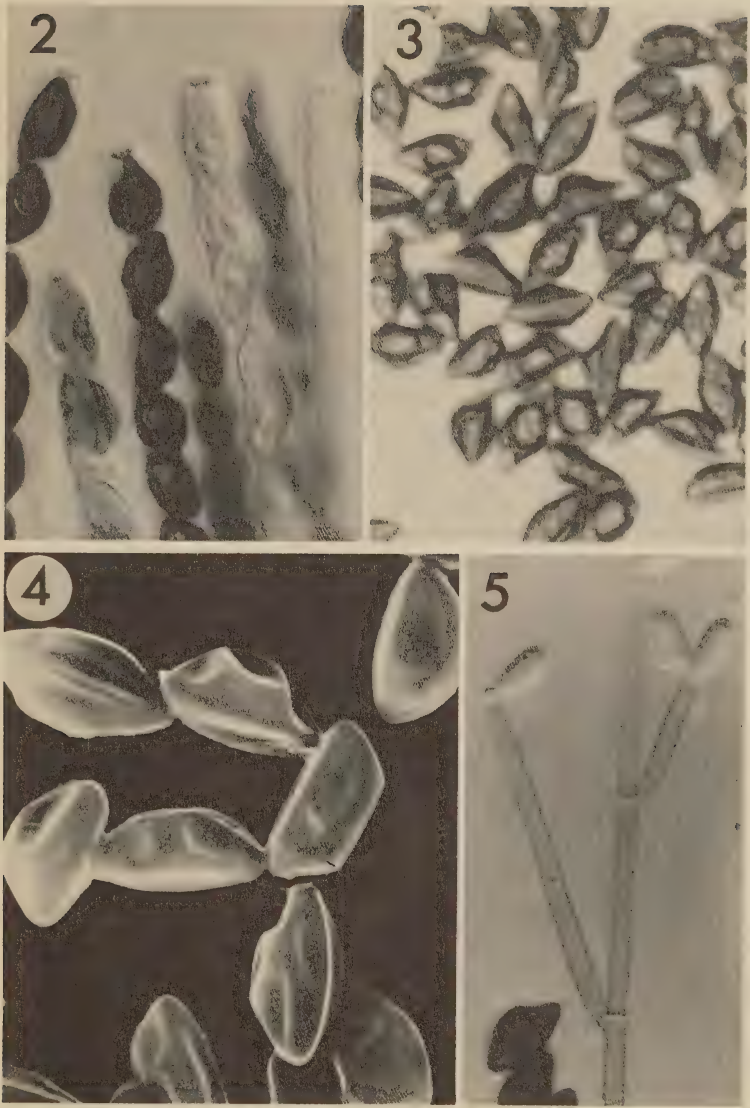
Conidiophora ex hyphis prostratis surgentia, erecta vel suberecta, recta vel plus minusve flexuosa, brunnea, septata, verrucosa, 70-160 x 2.5-3 µm, superne saepe ramificantia. Cellulae conidiogenae polyblasticae, discretae, terminales et in penicillis ordinatae, 2-4 verticillatae, cylindricae, 10-25(-30) x 2-3 µm, pallide brunneae, verruculosae, ad apicem nodulosae. Conidia ex denticulis terminalibus successivis singulatim producta, continua, hyalina, obovoidea vel ellipsoidea, 4.5-10 x 3-4 µm, levia vel parum verruculosa, ad basim cicatrice parva affixa.

Coloniae in agaro "potato-carrot" tarde crescentes, planae, floccosae, constantes ex mycelio basali coacto tenui et peritheciis numerosis, brunneo-griseae vel vinosobubalinae vel submurinae; conidia limitata; reversum brunneo-griseum vel murinum.

Holotypus: cultura, NHL 2983, ex limo ad lacunam artificialem, Nishiyama, Nagasaki, in Japonia, 14.i.1987, a S. Ueda, isolata. In collectione fungorum "National Institute of Hygienic Sciences (NHL), Tokyo, Japan".

Etymology: Latin, *lacunosus* =covered with depressions, referring to the depressions on its ascospore wall.

Perithecia scattered, nearly superficial to semi-immersed, non-stromatic, pyriform to broadly ovoid, 210-310 x 105-170 µm, dark brown to black, usually covered around the base of the neck with a few short hairs; hairs brown,



Figs. 2-5. *Calceomyces lacunosus,* NHL 2983.
2. Apical portions of asci. x1000. 3. Ascospores. x1000. 4. Ascospores (SEM photograph). x2000.
5. Conidiogenous cells and conidia. x1000.

straight, sparsely septate, smooth-walled, 30-65 x 4-5 µm near the base, tapering abruptly to the rounded apex; neck conical to short cylindrical, 80-130 x 65-95 µm, dark brown, covered with small black papillae, with a wide ostiole. Peridium about 15 µm thick, membranaceous, with an outer surface of a loosely interwoven network of hyphae, composed of textura intricata or textura angularis, 3-5-layered; with an outer layer consisting of dark brown, radially compressed, thick-walled, 2.5-5 µm diam cells and inner layers of hyaline, angular and flattened, thin-walled, 3-10 µm diam cells. Periphyses numerous, hyaline, filiform, septate, inflated at the base, tapering to the apex. Asci 8-spored, cylindrical, 90-125 x 8-9 µm (p.sp. 60-70 µm long), rounded above, with a small, flattened, ring-like structure in the apex (staining blue in Melzer's solution) measuring 3 µm diam and 1 µm high, tapering below into a short to fairly long stipe, rather persistent; paraphyses numerous, mixed with the asci, hyaline, septate, filiform to somewhat swollen, measuring 3-5 µm diam. Ascospores obliquely uniseriate, initially hyaline and smooth, then becoming dark brown and opaque, wooden shoe-shaped, (9.5-)10-14 x 5-6 x 6-6.5 µm, more or less acuminate at both ends, nearly trapezoid in side view and fusiform or ellipsoid in face view, reticulate with irregular ridges and shallow depressions, one side (sole-face) flattened and smooth-walled, with a longitudinal germ slit which extends almost to the ends of ascospore along the sole-face, upon germination rupturing at the germ slit and producing one to two germ tubes; gelatinous sheath hyaline and thin.

Mycelium composed of hyaline to pale yellow-brown, branched, often anastomosed, 1.5-2.5 µm diam, septate, smooth-walled hyphae. Perithecial initials composed of coiled branches of the vegetative hyphae. Conidiophores arising from prostrate hyphae, erect or suberect, straight or more or less flexuous, brown, septate, verrucose, 70-160 x 2.5-3 µm, often bearing one to two branches in the upper portion; branches brown, 12-36 x 2-3 µm, verrucose. Conidiogenous cells polyblastic, discrete in a whorl at the apex of the conidiophore stipe or branched, arranged penicillately, 2-4 in the verticil, appressed or divergent, cylindrical, 10-25(-30) x 2-3 µm, pale brown, verruculose, fading above and tapering abruptly, inflated, nodulose, 2-2.5 µm wide at the apex. Conidia acropleurogenous, sympodially produced on short denticles, forming a false head, continuous, hyaline, obovoid or ellipsoidal, 4.5-10 x 3-4 µm, smooth-walled or very slightly verruculose, with a small scar at the base.

Colonies on potato-carrot agar (PCA) growing slowly, attaining a diameter of 25-27 mm in 21 days at 25°C, plain, more or less floccose, consisting of a thin basal felt, with surface growth becoming granular in appearance due to the development of numerous black perithecia, overgrown but not obscured by a loose network of aerial hyphae, brownish gray (M. 7D2, after Kornerup and Wanscher, 1978) or "Vinaceous Buff" to "Pale Mouse Grey" (Rayner, 1970); conidia limited in number, not influencing the colony appearance; odor slightly moldy; reverse brownish gray (M. 8E2) or "Mouse Grey" (Rayner).

Colonies on oatmeal agar growing as on PCA but rather velvety, producing abundant perithecia and conidia, reddish brown to grayish brown (M. 9E4-3) or "Mouse Grey" to "Fuscous Black" (Rayner); odor moldy; reverse grayish brown to brownish orange (M. 9F3-6C3) or "Vinaceous Grey" to "Fuscous Black" (Rayner).

At 37°C, growth is nil.

Isolation: activated sludge, Nishiyama water reservoir, Nishiyama, Nagasaki-shi, Japan, 14.i.1987, coll. S. Ueda, NHL 2983 (Holotype).

The culture of the holotype of *C. lacunosus* was sent for deposit to the Cryptogamic Herbarium, Department of Botany, University of Toronto (TRTC).

From scanning electron microscope observations, the light-colored ascospores of some applanate *Hypoxylon* species have intricately punctate or reticulate walls (Rogers, 1977). Ascospores of species of *Camillea* are also observed to have similar reticulated surfaces (Rogers, 1979). Jong and Davis (1974) isolated *Areolospora,* a monotypic genus, from a soil sample collected in Colombia, South America. Subsequently Hawksworth (1980) reported that *Sordaria bosensis* Das (1962) and *Coniochaeta microspora* Reddy et Bilgrami (1969) were found to be conspecific with *Areolospora terrophila* Jong et Davis. Thereby the combination *Areolospora bosensis* (Das) D. Hawksworth was proposed. *Areolospora bosensis* produces stromatic perithecia and conidial structures referrable to *Sporothrix* in pure culture; characters of both morphs are typical of the Xylariaceae. Its ascospores are characterized by an ornamentation consisting of a verrucose wall with irregular nodules and devoid of distinct germ slits. The coarsely reticulate ornamentation on the ascospores of *Calceomyces lacunosus* is quite unique in that unlike most forms with this type of ornamentation, it consists of irregularly arranged thick ridges and large shallow depressions.

Studies of conidial states of xylariaceous fungi indicate that the form-genus *Nodulisporium* and morphologically allied hyphomycetes are characteristic for several members of *Hypoxylon,* especially in sections Hypoxylon, Annulata and Papillata, as well as some of *Biscogniauxia* (=*Nummulariella*), *Daldinia* and *Entonaema* (Greenhalgh and Chesters, 1968; Jong and Rogers, 1972; Martin, 1967; Rogers, 1979, 1982; Callan and Rogers, 1986). Therefore, the production of this type of anamorph in *C. lacunosus* indicates a taxonomic relationship with these xylariaceous fungi.

The amyloid plug structure in the ascus of *C. lacunosus* is typical of those found in genera of the Xylariaceae such as *Hypoxylon* (section Applanata), *Camarops, Nummulariella, Theissenia* and *Camillea* (Martin, 1967); this apical plug is a further indication of similarities with some of these fungi included in the Xylariaceae.

ACKNOWLEDGMENT

Appreciation is expressed to Dr. J.C. Krug of the University of Toronto for his useful suggestion and reviewing the manuscript.

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MYCOTAXON

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OVULARIOPSIS LAWSONIAE SPEC. NOV.

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Lawsonia inermis L. is known as host of Leveillula taurica s.l. from India and Saudi Arabia. Phyllactinia guttata s.l. has been recorded on Lagerstroemia indica from the U.S.A. (Amano 1986). Lawsonia and Lagerstroemia belong to the family Lythraceae. Recently a conidial state belonging to Phyllactinia (Ovulariopsis) has been collected in Hyderabad (India). The foot-cells of the conidiophores are twisted. Phyllactinia dalbergiae on legumes is the only known species in this genus with twisted foot-cells of the conidiophores (Braun 1987). The fungus on Lawsonia is different and must be described as new species.

Ovulariopsis lawsoniae spec. nov.

Mycelium hypophyllous, whitish-greyish, hyphae internal and external, hyphae straight to flexuous, subnodulose, subgeniculate, septate, 2-7.5 µm wide, appressoria solitary or in pairs, opposite, nipple-shaped, curved or irregularly lobed, ca 2-5 µm, conidiophores arising from the outer mycelium, erect, long and slender, (100-) 120-200 (-250) x 5-10 µm, composed of a very long foot-cell and (0-) 1-2 (-3) shorter apical

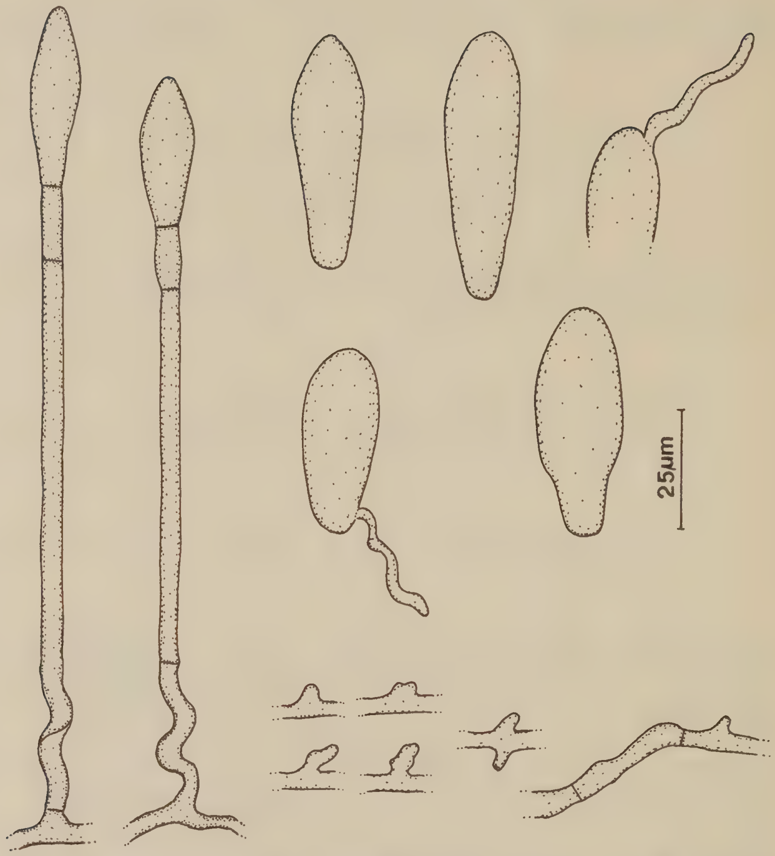

Fig. 1. Ovulariopsis lawsoniae spec. nov., conidiophores, conidia, germ tubes, appressoria, hyphal segment. U. Braun del.

cells, terminal conidiogenous cell occasionally swollen, basal part of the foot-cells undulate to helically twisted, basal septum occasionally somewhat away from the branching point of the mycelium, conidia formed singly, ± clavate, 50-120 x (13-) 16-23 (-28) µm, apex obtuse or occasionally subacute, germ tubes 1 or 2 per conidium, subapical or near the base, twisted, 10-100 x 2-5 µm, simple, rarely branched. Fig. 1.

Mycelium hypophyllum, griseolo-albidum, effusum. Hyphae rectae vel undulatae, subnodulosae, subgeniculatae, septatae, 2-7.5 µm latae. Appressoria non lobata vel lo-

bata. Conidiophora hyalina, (100-) 120-200 (-250) x 5-10 µm, 0-3-septata, recta, prope basim flexuosa-tortuosa. Conidia solitaria, clavata, 50-120 x (13-) 16-23 (-28) µm. Tubi germinativi prope apicem vel basim oriundi, 10-100 x 2-5 µm.

Holotypus: on Lawsonia inermis L. (Lythraceae), India, Hyderabad, Novodaya Colony, Nov.-Dec. 1987, leg. Bagyanarayana (HAL).

Additional material: on Lawsonia inermis L., India, Hyderabad, 18-1-1988, leg. Ravinder (HAL).

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MYCOTAXON

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A NEW SPECIES OF THE GENUS **DENDRYPHIOSPHAERA**

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Dendryphiosphaera parvula sp.nov., a dematiaceous hyphomycete isolated from a submerged decaying twig is described and compared with **Brachysporiella.** A key to the known species of **Dendryphiosphaera** is provided.

The genus **Dendryphiosphaera** was erected by Lunghini & Rambelli(1978) with **D.taiensis** as the type species. The genus is characterised by having large, simple, setiform conidiophores bearing small, 2-septate conidia on subglobose to ovoid often catenate conidiogenous cells terminally and in verticils along the apical zone of the conidiophores. **D.taiensis** is known only from the type locality. **Dendryphiosphaera** remained monotypic until Rao & Hoog(1986) described **D.minuta** from India. It differs from the type species in having smaller, obovoid conidia.

Recently we found a dematiaceous fungus belonging to this anamorph genus, sporulating on a length of an unidentified decaying twig collected from the bottom of a freshwater stream at Pasuh Forest Reserve, Malaysia. The twig had been incubated in a moist chamber for several days at 25 – 28°C. The Malaysian isolate appears to be quite distinct and is described below as a new species.

Dendryphiosphaera parvula sp.nov. Figs. 1 – 2

Fungi Imperfecti, Hyphomycetes dematiacei. Mycelium ex hyphis laevibus, ramosis, septatis, brunneis, 1.5 – 2.5 μm latis compositum. Conidiophora ex hyphis vegetativis lateralia, macronematosa, mononematosa, setiformia, solitaria, simplicia, erecta, recta vel modice curvata, laevia, et tenuitunicata, atrobrunnea, sursum pallidiora, 83 – 185 μm alta, basi inflata, supra basim 5 – 8 μm crassa, ad 3 – 4 μm attenuata, 5 – 11 septata; septis 16 – 22 μm distantibus divisa. Cellulae conidiogenae terminales et in verticillo dispositae, dilute brunneae, subglobosae vel ovoideae, 5 – 6 μm x 3.5 – 4 μm, laeves, fere

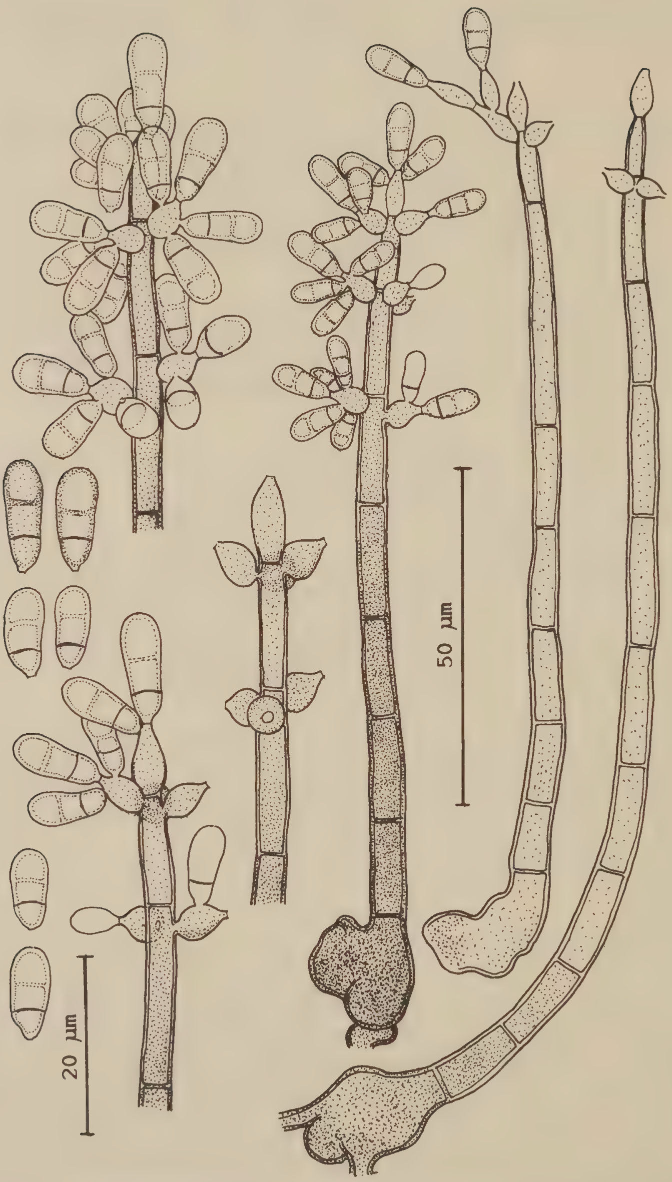

Fig.1. **Dendryphiosphaera parvula.** Conidiophores and conidia from twig

crassitunicatae. Conidia laevia et fere crassitunicata, pallide brunnea, obovoidea, 8 – 12 µm x 3.5 – 4.5 µm, biseptata, septo basali atra.

Ex ramulum putridum in flumine immersi, Pasuh Forest Reserve, Negri Sembilan, Malaysia, A. Nawawi, 24.9.1987, IMI 322553 holotypus.

On the natural substrate the mycelium appears to be mainly superficial, brown, smooth, septate, measuring 1.5 – 2.5 µm wide. Conidiophores lateral, macronematous, mononematous, setiform, solitary, simple, erect, straight or slightly curved, smooth, thick-walled, dark brown below, becoming paler above, basally inflated to 16 – 20 µm, 5 – 8 µm wide above, narrowing to 3 – 4 µm, 83 – 185 µm tall, 5 – 11 septate; septa formed every 16 – 22 µm. Conidiogenous cells polyblastic, pale brown, moderately thick-walled; apical conidiogenous cells slightly longer measuring 7 – 9 µm long, lateral conidiogenous cells subglobose to ovoid, 5 – 6 µm x 3.5 – 4 µm, arranged in verticils of 1 – 4 cells along the apical zone of the conidiophores. Lateral conidiogenous cells mostly arise just below a septum. Each conidiogenous cell can produce up to 7 conidia. Conidia smooth, moderately thick-walled, pale brown, obovoid, 2-septate, basal septum distinctly dark and euseptate, while the distal septum is lighter and distoseptate, 8 – 12 x 3.5 – 4.5 µm with narrow, thin, unpigmented scar. Apical conidia from the terminal and lateral conidiogenous cells tend to be larger.

Conidia germinate slowly on agar media by producing a germ-tube from the basal scar. On CMA the colonies are slow-growing, compact, pulvinate, pale at first, becoming light brown to brown and covered with a beige to brown powdery accumulation of conidia. Mycelium immersed and superficial, composed of branched, septate, smooth, light brown 1 – 2 µm wide hyphae. Conidiophores arise laterally or terminally from the repent vegetative hyphae, macronematous to semi-macronematous, and are much shorter and narrower than those formed on the natural substrate. Many are only 1 – 2 cells in length terminating in a conidiogenous cell. Occasionally the conidiogenous cells arise directly from the vegetative hyphae. Conidia produced in cultures tend to be narrower with slightly incurved lateral wall.

In terms of conidiogenesis, spore morphology and colour, **D.parvula** is very similar to **D.minuta**. However, there are essential differences between the two species. Conidia of **D.parvula** are smaller, rarely exceeding 12 µm long x 4.5 µm wide.

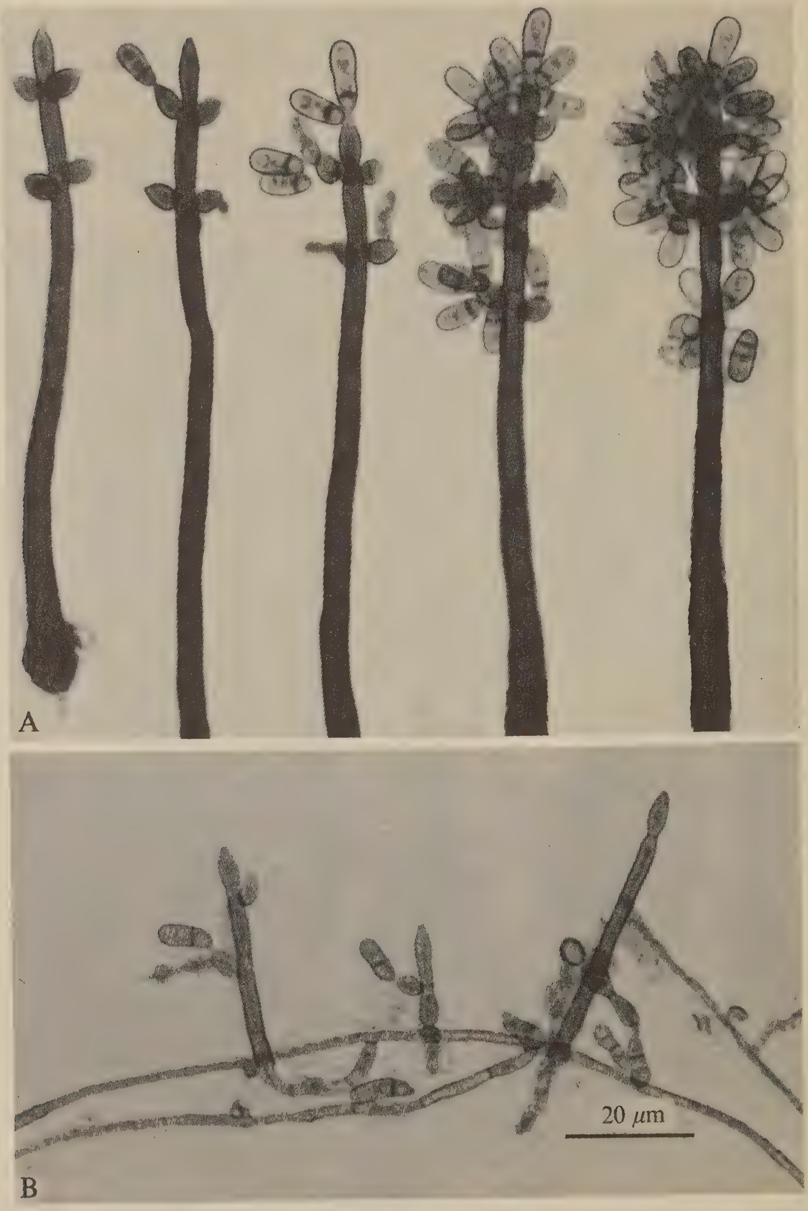

Fig.2. **Dendryphiosphaera parvula.** (A) Conidiophores and conidia from twig; (B) conidiophores and conidia from culture

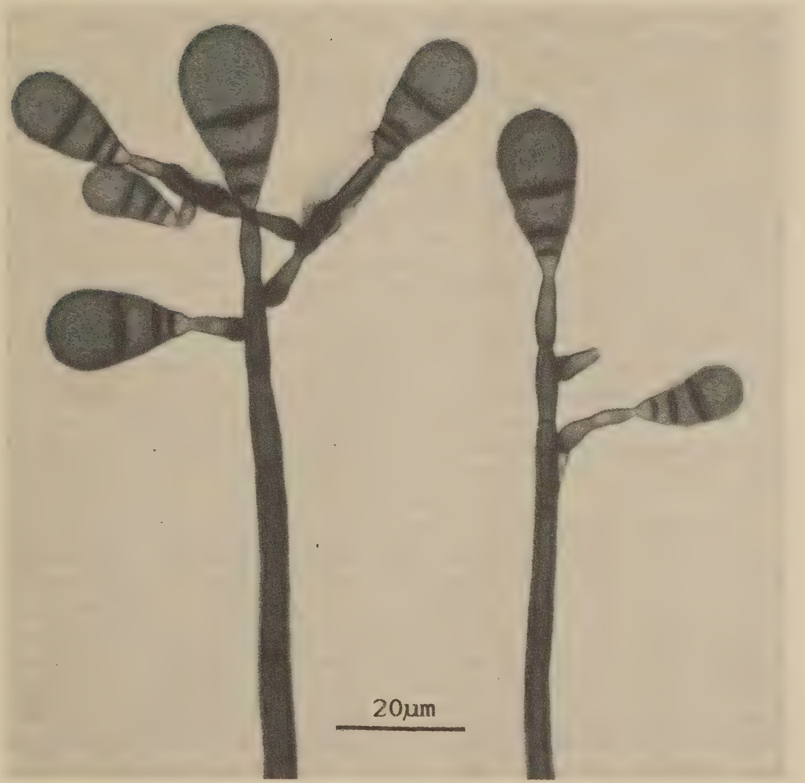

Fig.3. **Brachysporiella gayana.** Conidiophores and conidia

They are formed on polyblastic conidiogenous cells that rarely proliferate.

Key to the species of **Dendryphiosphaera**

Conidia cylindrical with rounded apices, up to 16 µm long; septa equally spaced . . . . **D.taiensis**

Conidia obovoid up to 14 µm long x 5 – 6 µm wide with the distal septum near the middle; basal cell small and light-coloured . . . . **D.minuta**

Conidia obovoid up to 12 µm long x 3.5 – 4.5 µm wide with dark basal euseptum . . . . **D.parvula**

Rao & Hoog(1986) commented that there is little difference between **Dendryphiosphaera** and the type species of **Brachysporiella, B.gayana** Batista in their conidial apparatus, but they were reluctant to lump all **Brachysporiella**-like fungi into one genus and preferred to maintain **Dendryphiosphaera** as conceived by Lunghini & Rambelli(1978).

After examining different isolates of **B.gayana** from Malaysia we are of the opinion that **Dendryphiosphaera** is quite different. In **B.gayana** the conidiophores are rather variable. Some consist of a simple main stalk with a terminal conidiogenous cell. Others bear solitary or pairs of conidiogenous cells or short 1 – 4 celled branches which themselves bear a solitary terminal conidiogenous cell (Fig.3). These lateral branches may bear secondary and occasionally tertiary branches, each ending in a conidiogenous cell. Further the conidiophores and their lateral branches proliferate percurrently after conidial secession which does not occur in **Dendryphiosphaera.** Conidia of **Brachysporiella** spp. are generally bigger, darker and thick-walled.

Dendryphiosphaera, therefore, has come to encompass those dematiaceous hyphomycetes with rather large, simple setiform, septate conidiophores bearing terminally a cluster of subglobose to ovoid conidiogenous cells that may proliferate to produce chains of cells. Beneath the upper one to three septa the conidiophores also bear conidiogenous cells which may be solitary or in clusters, usually in whorls. Conidia are blastic, comparatively small, 2-septate, pale to brown, cylindrical with rounded apices to obovoidal, moderately thick-walled with narrow, thin, unpigmented basal scars.

We thank Professor J. Webster, University of Exeter, for reviewing the manuscript.

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BOTRYOSPORIUM HUGHESII, A NEW SPECIES FROM AFRICA

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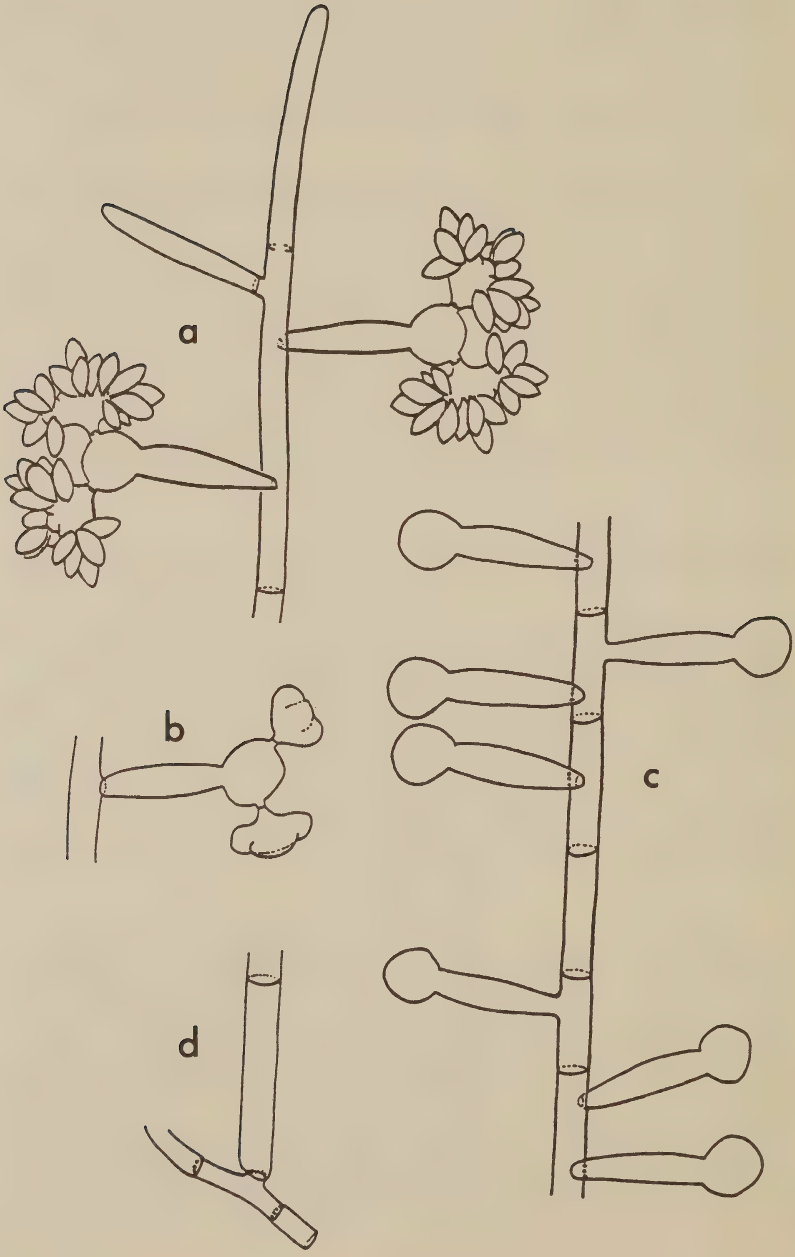
During the course of our nomenclatural study (Vincent & Blackwell, 1987) and ongoing revision of the genus Botryosporium, a single herbarium specimen was discovered out of nearly one thousand examined which did not correspond to any previously published species. It is here published as a new species, B. hughesii, in the hope that additional material of the species will be discovered. This fungus is named in honor of its collector, Dr. Stanley J. Hughes.

Botryosporium hughesii Vincent & Blackwell, sp. nov. Figs. 1, 2.

Mycelium superficiale, hyalinum, septatum; conidiophora erecta, non dichotoma, hyalina, septata, usque ad 2300 µm x 13-16 µm, cum ramulis fertilibus lateralibus, et apice obtuso; ramuli laterales recti acrpetalio maturantes, (70-)80(-90) µm x 11.5 µm, cum globo inflato in extremo ad 21 µm diametrum, et cum (2-)3 ampullis lateralibus; ampullae specie paulo trilobae, circa 16 x 16 µm, efferentes simul blastoconidia in lobis; conidia levia, non septata, elliptica vel obovata, (10-)13(-14) µm x (6-)7(-8) µm.

Mycelium superficial, hyaline, septate. Conidiophores erect, simple, hyaline, septate, to 2300 µm x 13-16 µm, with fertile lateral branchlets and a blunt apex. Lateral branchlets straight, maturing acropetally, (70-)80(-90) µm long, 11.5 µm wide at the midpoint, with a terminal spherical vesicle to 21 µm in diameter, and with (2-)3 ampullae arising laterally from the vesicle. Ampullae slightly 3-lobed, ca. 16 x 16 µm, producing conidia blastically on the lobes. Conidia smooth-walled, aseptate, ellipsoidal to obclavate, (10-)13(-14) µm x (6-)7(-8) µm. Conidia slightly rugose when viewed with a


a
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scanning electron microscope, but appearing smooth at 1000x in the light microscope.

HOLOTYPE: On leaves of Saccharum officinarum, S.J. Hughes 488, 10 May 1949, Takoradi, Ghana, West Africa (IMI 38568). Photographs, negatives and microscopic slides prepared from the type are deposited at MU. This specimen was cited by Hughes (1953) as Botryosporium longibrachiatum (Oudemans) Maire.

The type specimen is too mature to allow complete observation of branchlet morphology, and thus the description of the species may need to be emended if additional material is found. However, the new species is readily distinguishable from B. longibrachiatum, which it most closely resembles, by the structure of the branchlets. In B. hughesii, the inflated apices of the lateral branchlets are spherical, while those of B. longibrachiatum are hastate or at least oblong and more pointed at the apex. Lateral branchlets in B. hughesii are persistent, while those of B. longibrachiatum are deciduous as the fungus ages.

This work was supported in part by grant no. 62 from the Willard Sherman Turrell Herbarium Fund (MU). We wish to thank Connie Bricker for her able assistance on the scanning electron microscope, without which certain characteristics of this species could not have been elucidated. Dr. Judith de Luce, Chair, Department of Classics, Miami University, assisted with the Latin diagnosis. The manuscript was reviewed by Dr. S.J. Hughes and Dr. K.A. Seifert.

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FIG. 1. a. apical portion of conidiophore b. lateral branchlet with ampullae c. mid-portion of conidiophore with old branchlets which have lost the ampullae d. basal portion of conidiophore, showing attachment to hypha (all x485).

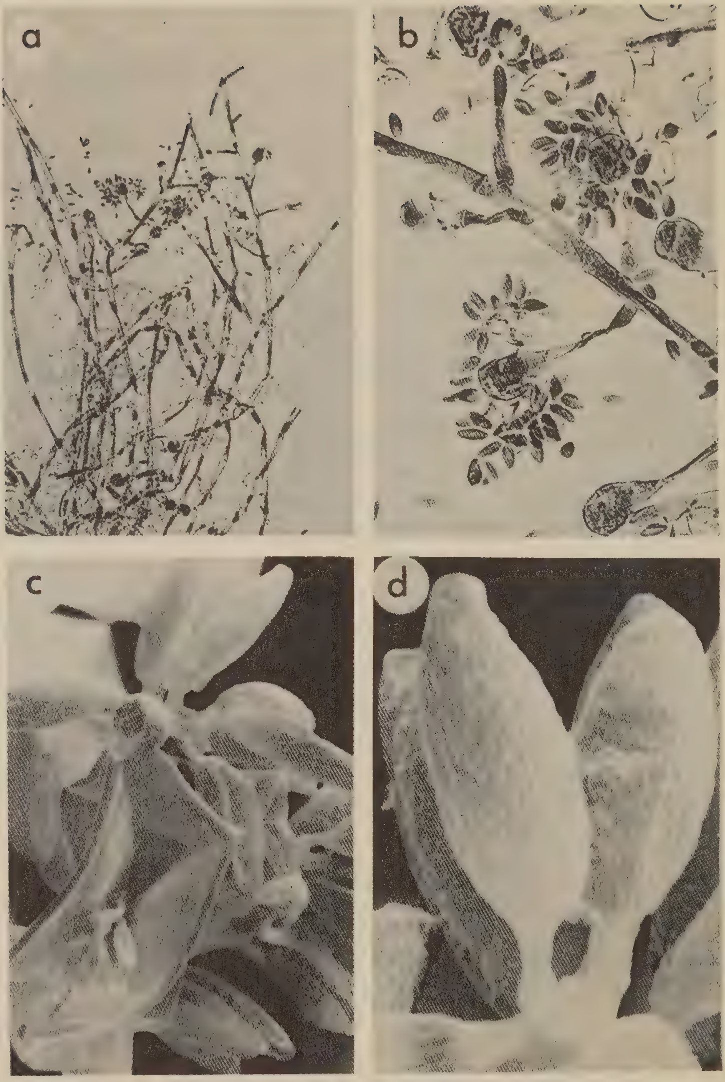

FIG. 2. a. light micrograph, conidiophores, x80 b. light micrograph, fertile portion of conidiophore, x350 c. scanning electron micrograph, collapsed branchlet vescicle, ampulla and conidia, x2230 d. scanning electron micrograph, conidia, showing attachment to ampulla, x6260.

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GLOEOSYNNEMA, A NEW GENUS OF SYNNEMATOUS HYPHOMYCETES WITH BASIDIOMYCETOUS AFFINITIES

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Abstract

A new anamorph genus, **Gloeosynnema** Seifert & Okada, is established and the type species **G. ochroleucum** (Penzig & Sacc.) Seifert & Okada is redescribed and illustrated as a new combination. The genus is characterized by subgelatinous, determinate synnemata, percurrently or rarely sympodially proliferating conidiogenous cells on sparsely branched conidiophores, and oblong-ellipsoidal, slimy, dikaryotic ameroconidia. Clamp connections on the stipe hyphae and the dikaryotic conidia indicate that the species is a Basidiomycete, but the teleomorph is unknown.

Introduction

In his revision of species attributed to *Stilbum* auct. non Tode and *Stilbella* Lindau, Seifert (1985) excluded *Stilbum ochroleucum* Penzig & Sacc. from *Stilbella*, commenting that the stipe hyphae had clamp connections. We here present a description and illustration of the species, discuss its affinities, and describe a new anamorph genus for it. The descriptive terminology for synnema morphology and conidiophore branching was explained in detail by Seifert (1985).

Gloeosynnema Seifert & Okada, **anam. gen. nov.**

Genus Hyphomycetum synnematicum, conidiomatibus determinatis, subgelatinosis, in KOH haud discolorantibus, massam conidiorum apicalem mucidam ferentibus. Hyphae stipitis parallelae, hyalinae, leves, fibulatae. Conidiophora vel simplicia vel semel monochasialia. Cellulae conidiogenae cylindricae, hyalinae, percurrenter vel raro sympodialiter proliferantes. Conidia unicellularia, ellipsoidea vel oblongo-ellipsoidea, hyalina, levia, dikaryotica, holoblastica.

Teleomorphosis ignota.

Holotypus: Gloeosynnema ochroleucum (Penzig & Sacc.) Seifert & Okada, leg. Penzig no. 40, Indonesia, Java , herb. BO 10143

Conidiomata synnematous or sometimes sessile, determinate, subgelatinous, not changing colour in 2% KOH or 85% lactic acid. *Hyphae of stipe* parallel, hyaline, with clamp connections. *Conidiogenous cells* cylindrical or slightly subulate, hyaline, usually proliferating percurrently or rarely sympodially. *Conidia* amerosporous, ellipsoidal to oblong-ellipsoidal, hyaline, dikaryotic, holoblastic, accumulating in a slimy mass.

Teleomorph unknown.

Type species: *Gloeosynnema ochroleucum* (Penzig & Sacc.) Seifert & Okada.

Gloeosynnema ochroleucum (Penzig & Sacc.) Seifert & Okada, **comb. nov. FIGS 1-16**

Stilbum ochroleucum Penzig & Sacc., Malpighia 15: 250. 1901. (Basionym)

Synnemata 125-500 *u*m tall, 25-250 *u*m wide, orange-brown, reddish brown, or light yellow, translucent, subgelatinous, slender to robust, cylindrical, clavate, cylindrical-capitate, rarely sessile and pustulate, unbranched, scattered to gregarious, sometimes with a white, filmy subiculum around the base. *Hyphae of stipe* 2-3 *u*m wide, hyaline, with clamps at most septa, frequent anastomoses and smooth walls up to 0.5 *u*m thick. *Marginal hyphae* irregularly swollen and constricted in some collections, 2-6.5 *u*m wide, with smooth walls up to 0.5 *u*m thick. *Conidiophores* unbranched, or branched once monochasially. *Conidiogenous cells* 30-65 *u*m long, 1.5-3 *u*m wide, terminal or lateral and terminal, cylindrical to slightly subulate, usually proliferating percurrently to produce inconspicuous annellations 1.5-2 *u*m apart, or rarely sympodially, without obvious denticles or detachment scars, often with a basal clamp, hyaline. *Conidial mass* 50-275 *u*m diam., yellow, orange or reddish brown, concolourous with or slightly darker than stipe, globose to subglobose, or somewhat flattened. *Conidia* 7-15 x 3-5 *u*m, one-celled, oblong-ellipsoidal to ellipsoidal or slightly clavate, often with a slightly truncate base, sometimes with a medial constriction, often with distinct guttules, hyaline.

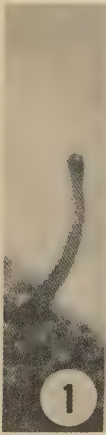
Habitat: Rotten wood.

Distribution: Indonesia, Japan.

Illustrations: Penzig and Saccardo, 1904, *Icones fungorum Javanicorum*, tab. LXXII, fig 3.

Material examined: Indonesia, Java, leg. Penzig no. 40 (holotype BO 10143, isotype PAD). Indonesia, Java, Bogor, on white-rotted wood, May 1924 (BO 8698). Japan, Ibaraki Pref., Mt. Tsukuba, leg. G. Okada nos 93, 94, 95, 5 Aug. 1982 and nos

FIGS 1-8. *Gloeosynnema ochroleucum.* 1. Habit photograph of synnema from isotype collection (PAD), x 30. 2. Habit photograph of synnemata from Japanese specimen, G.O. 94, x 50. 3. Habit photograph of sessile conidiomata from Japanese specimen, G.O. 105, x 50. 4. Conidia from isotype collection (PAD), x 1860. 5. Conidia from Japanese specimen, G.O. 105, stained with Safranin O, arrows indicating nuclei, x 2260. 6. Hypha from stipe of Japanese collection, G.O. 103, x 3040. 7. Detail of the apex of a conidiogenous cell showing annellations, G.O. 95, x 3170. 8. Synnema from G.O. 95, x 160. (Figs. 4, 6, 7. Nomarski optics. Figs. 5, 8. Bright field optics)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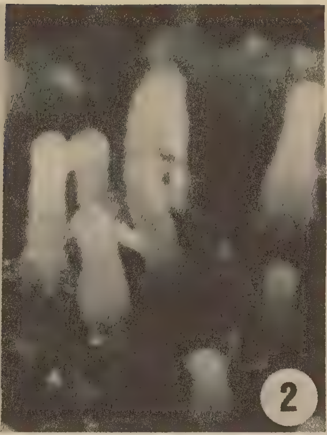
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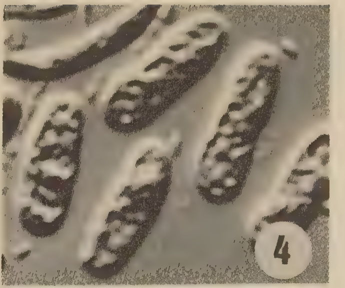
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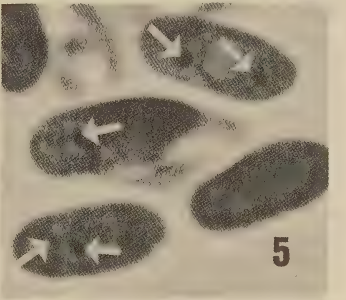
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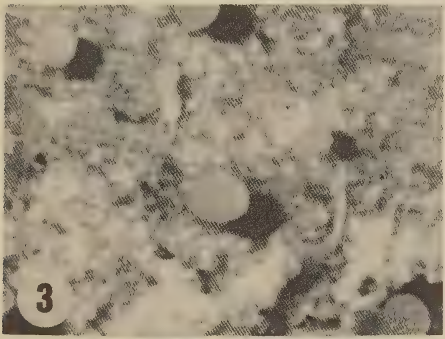
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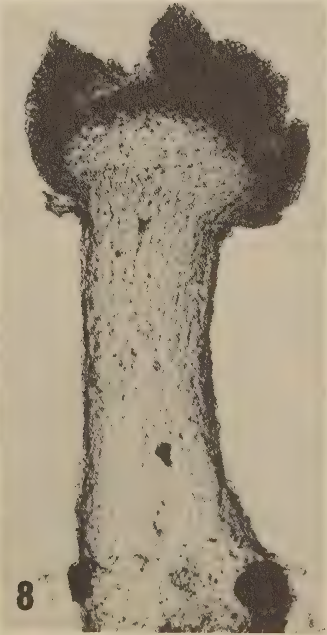
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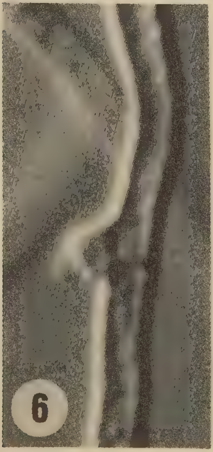
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221, 222, 30 July 1983 (herb. Okada). Japan, Ibaraki Pref. Tsuchirua, Shishizuka Pond, leg. G. Okada nos. 103, 104, 105, 6 Aug. 1982 (herb. Okada). Japan, Akita Pref., Kazuno, Osarizawa, leg. T. Aoki, 29 May 1986 (herb. Okada no. 722).

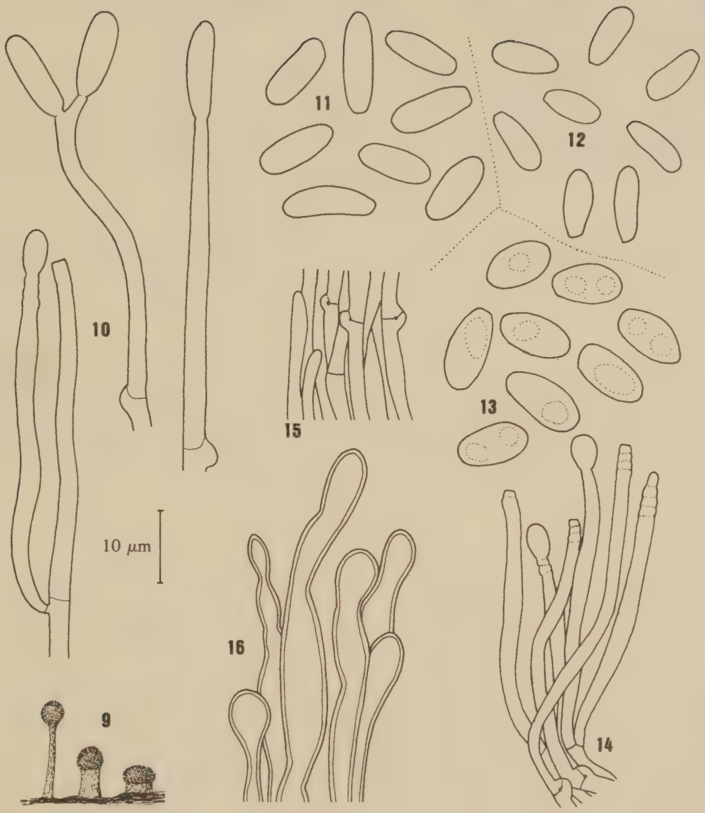
Discussion

Gloeosynnema is characterized by the determinate gelatinous synnemata, clamped hyphae, sparsely branched conidiophores, percurrently or sometimes sympodially proliferating conidiogenous cells, and ellipsoidal to oblong-ellipsoidal, dikaryotic ameroconidia. Among superficially similar synnematous hyphomycetes with ascomycetous affinities, *G. ochroleucum* should be compared with species of *Stilbella* Lindau, which produce fleshy synnemata, and *Dendrostilbella* Höhnel, which produce subgelatinous synnemata. Species of both genera have more highly branched conidiophores, phialidic conidiogenous cells, and smaller conidia (Seifert 1985). Several other genera of synnematous hyphomycetes are known that have basidiomycetous affinities. *Riessia semiophora* Fres. (teleomorph unknown) has petaloid conidia, produced on indeterminate synnemata and the hyphae of the stipe have clamp connections (Goos 1967, Goos and Tubaki 1973). *Sclerostilbum septentrionale* Povah (teleomorph *Collybia*, see Watling and Kendrick 1977) and the species of *Antromycopis* Pat. & Trab. (teleomorphs *Pleurotus*, see Pollack and Miller 1976) all produce ameroconidia in thallic-holoarthric chains (Cole and Samson 1979).

Recently, Bandoni and Oberwinkler (1982) described a genus of the Tulasnellaceae, *Stilbotulasnella* Oberw. & Bandoni, for a single species, *S. conidiophora* Bandoni & Oberw. Scattered tulasnelloid basidia are produced on a subiculum and upon the stipes of the synnemata, which produce dikaryotic, ellipsoidal ameroconidia in slime from percurrently proliferating conidiogenous cells. We believe that *Gloeosynnema ochroleucum* has affinities with the unnamed anamorph of *S. conidiophora*, which has smaller conidia and lacks clamp connections. Despite careful searching, we have been unable to locate basidia on any of the collections of *G. ochroleucum* we have seen. A decision on whether these two anamorphs are actually congeneric must await a critical evaluation of the numerous similar species, described and undescribed, that we have encountered.

Acknowledgements

This work was carried out in part while K.A.S. was a guest at the Centralbureau voor Schimmelcultures, Netherlands, and G.O. was at the Institute of Biological Sciences, University of Tsukuba, Japan. We thank our supervisors, Dr. R. A. Samson and Dr. K. Tubaki, for their advice and encouragment. We are grateful to the curators of BO and PAD for the loan of specimens, and to Dr. R. J. Bandoni and Dr. W. Gams for their reviews of the manuscript. Karen Lucas and Jorge Serrador kindly prepared the camera ready copy. The award of a Natural Sciences and Engineering Research Council of Canada Postgraduate Scholarship to K.A.S. was much appreciated.



FIGS 9-16. *Gloeosynnema ochroleucum* line drawings. 9. Habit. 10. Conidiogenous cells from isotype (PAD). 11. Conidia from isotype (PAD). 12. Conidia from BO 8968. 13. Conidia from G.O. 105. 14. Portion of the capitulum of G.O. 105. 15. Clamp connections on stipe hyphae, G.O. 105. 16. Marginal hyphae from isotype (PAD).

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STUDIES IN THE GENUS PHOMA. XIII. CONCERNING PHOMA EXIGUA VAR. EXIGUA, A COSMOPOLITAN, UBIQUITOUS FUNGUS ON DISEASED AND DEAD PLANT MATERIAL.

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ABSTRACT

Phoma exigua var. *exigua* is described and illustrated. An account is given of some of the perplexity surrounding the taxon, resulting from the application of numerous binomials to it. Its cultural characteristics and the anatomy of its pycnidial wall are documented. The distinctions between it and taxa with which it can be confused, including the other recognized varieties of *P. exigua*, are noted.

INTRODUCTION

As has been alluded to several times in preceding papers of this series (e.g. Morgan-Jones and White, 1983; White and Morgan-Jones, 1984), much confusion has existed in the past over definition of species in the genus *Phoma* Sacc. This has occurred, in part, because species concepts have not been based predominantly on detailed morphological characteristics, but rather tied unduly to host relationships. In essence, a largely substrate-based taxonomy has resulted in literally hundreds of binomials being proposed for what are, in actuality, a few ubiquitous species. The magnitude of the resultant chaos was the subject of a review by Shear (1923) who concluded that referring a fungus to *Phoma* was "about as scientific and satisfactory a method of classifying fungi as dumping miscellaneous letters into a waste-basket would be of filing correspondence." That may have been a bit of an over-reaction but it nevertheless indicates the long-standing dissatisfaction that has been felt by researchers confronted with the over two thousand specific epithets extant in the genus. A parallel situation, but with somewhat fewer names involved, exists in several other genera of the Coelomycetes, for example in *Ascochyta* Lib. (Punithalingam, 1979). Because of the number of names involved and the problem of typifying with certainty many of them, a comprehensive revision of all described species is a dauntingly difficult, if not impossible, task. With the present resources and effort given to the subject, we can, at best, only hope to provide improved accounts of the distinguishing characteristics of the most commonly encountered species and give some indication of synonymies. Where a particular species is restricted in its host range, mostly by being a specialized plant pathogen, taxonomic problems are more easily resolved since comparatively few names have, in most cases, been applied to such entities. Where species are ubiquitous and widespread in their distribution, more often than not an inordinately large number of binomials

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have been applied to them, making for long lists of synonyms and confusion in the literature. Such is the case with *P. exigua* Desm. and the type species of the genus *Phoma*, *Phoma herbarum* Westd., which form, respectively, the subject of this and the succeeding paper of this series. The same is true of *P. macrostoma* Mont., treated previously (White and Morgan-Jones, 1984). These species have a wide host and substrate range and, not surprisingly, many different names and ranks have been applied to them, including numerous 'formae' and varieties. As could be expected, they have also, on a number of occasions, been confused with each other. For example, *P. exigua* var. *minor* Desm. and *P. exigua* var. *ranunculorum* Desm. are *P. herbarum*, whereas *P. herbarum* f. *brassicae* Sacc., *P. herbarum* f. *schoberiae* Sacc., and *P. herbarum* var. *dulcamaricola* Bub. are *P. exigua* var. *exigua* (Boerema, 1970; Boerema and Höweler, 1967)! *Phoma herbarum* f. *lilacis* Sacc. is now *P. exigua* var. *lilacis* (Sacc.) Boerema whereas *P. herbarum* f. *rubi* Sacc. is considered to be a synonym of *P. macrostoma* (Boerema and Dorenbosch, 1970). In addition to being confused with other species intragenerically, *P. exigua* var. *exigua*, because of frequent production of both non- and one-septate conidia, has suffered the nomenclatural fate of some other *Phoma* species, such as *P. lycopersici* Cooke [anamorph of *Didymella lycopersici* Kleb.], having the same characteristic. Such fungi have often been classified in either *Ascochyta* Lib. or *Diplodina* Westd. In fact, of the more than one hundred names that have been proposed for *P. exigua* var. *exigua* well over twenty binomials are in *Ascochyta* (Boerema and Dorenbosch, 1973), including the widely used *A. phaseolorum* Sacc. (Boerema, 1972).

Phoma exigua is a fungus associated with stem and leaf lesions of a wide variety of host plants and with rotting fleshy roots and tubers. It is also ubiquitous on decaying plant material, particularly herbaceous stems, and in soil (Boerema and Höweler, 1967; Domsch *et al.*, 1980). It has been recorded on more than two hundred phanerogamic plant genera (Boerema and Dorenbosch, 1973). Crossan (1958) reported what he believed to be *P. exigua* var. *exigua* [as *Ascochyta phaseolorum*] from a wide range of host plants including cotton, cowpea, eggplant, hollyhock, okra, pepper, snapbean, soybean, tobacco and tomato, in North Carolina, U.S.A. Isolates from these hosts were found to be morphologically, physiologically and pathogenically similar, as reflected by cross-inoculation studies. Six additional specific epithets in *Ascochyta*, originally applied on the basis of association with one or other of these hosts, were considered by Crossan to be untenable. Not all his conclusions in this regard can, however, be upheld since, for one thing, he considered *A. lycopersici* (Plowr.) Brun. [as *A. lycopersici* Brun.] to be a synonym of *A. phaseolorum*. *Ascochyta lycopersici* (Plowr.) Brun. [≡ *Sphaeronaema lycopersici* Plowr., now accepted as a facultative synonym of *Phoma lycopersici* Cooke, the anamorph of *Didymella lycopersici* Kleb., (see Boerema and Dorenbosch, 1973; Morgan-Jones and Burch, 1988)] is a different fungus. In addition, *A. abelmoschi* Harter and *A. gossypii* Syd., considered by Crossan to be synonyms of *A. phaseolorum*, are also based on entities other than *P. exigua* (Boerema, 1972). *Ascochyta gossypii* Syd. is a synonym of *A. gossypii* Woron., the causal organism of "wet weather blight" of cotton (Holliday and Punithalingam, 1970). In spite of a rather extensive investigation, certain lack of critical consideration of morphology, together with absence of type studies, makes the work of Crossan less useful than it could otherwise have been. Alcorn (1968) also reported a wide host range for *P. exigua* [again as *A. phaseolorum*] in Australia. Sutton (1980) reported collections and cultures, worldwide in origin, from seventy-four different host genera, and from soil, dung and litter.

While recognizing that the numerous names extant in the literature represent one entity, which functions as a saprophyte, a weak wound pathogen, or a secondary invader of diseased tissue, attention has been paid to the fact that a number of morphologically similar or identical forms differ in their pathogenic capacity, in host specificity, and sometimes in colony appearance *in vitro*. With this in mind, a varietal concept has been adopted to accommodate these differences and those isolates having demonstrably variant physiological or cultural characteristics have been segregated accordingly. As we shall discuss later, there has been uncertainty about appropriateness of varietal rank application. In the genus *Phoma* in general, as we have mentioned previously (Morgan-Jones and Burch, 1987a, 1987b), uneven varietal application, in the sense of being based on unequal degrees of difference, raises a question about the usefulness of the varietal concept and the suitability, or even practicality, of its utilization. The same type of problem is often encountered when authors adopt 'formae' or 'formae speciales' concepts. As pointed by Hawksworth (1974), the form ('forma' *)* is probably the most misused rank in taxonomy and is best avoided except where there is a clear source of variation. In the case of special form ('forma specialis' *)*, physiological reaction to particular host plants is the central distinguishing feature, although minor morphological differences may be included (Hawksworth, 1974).

The causal organism of damping off and footrot of flax [*Linum usitatissimum* L.], long known as *Ascochyta linicola* Naoum. & Vass., was recognized by Maas (1965) as being morphologically similar to *P. exigua* but to differ from it in its cultural characteristics, particularly by slower and more compact growth. On the basis of these observations, Maas transferred *A. linicola* into *P. exigua* as a variety [var. *linicola* (Naoum. & Vass.) Maas], thereby bringing *P. exigua* var. *exigua* automatically into existence. Dennis (1946), in his detailed study of some British fungi ascribed to *Phoma*, had earlier described some isolates belonging to the *P. exigua* complex under his group II designation and recognized his strains 8 and 9, originating from stem rot of flax, to represent "a species distinct from the other fungi in group II" [which also included seven isolates of var. *exigua* and one (strain 6) of var. *inoxydabilis* Boerema & Vegh (see below)] (Boerema, 1976). Boerema and Höweler (1967) accepted the varietal rank given the epithet *linicola* Naoum. & Vass. by Maas (1965), but Malcolmson and Gray (1968) regarded it as merely a special form on the basis that it is distinguishable physiologically but scarcely or not at all morphologically. Accordingly they published the combination *P. exigua* Desm. f. sp. *linicola* (Naoum. & Vass.) Malcolmson & Gray. The varietal status has subsequently been upheld (e.g. by Boerema, 1976; Sutton, 1980). Boerema (1976) described it as having relatively uniform colonies with dominating black tinges and growing appreciably slower than var. *exigua* on oatmeal agar at 20-22C.

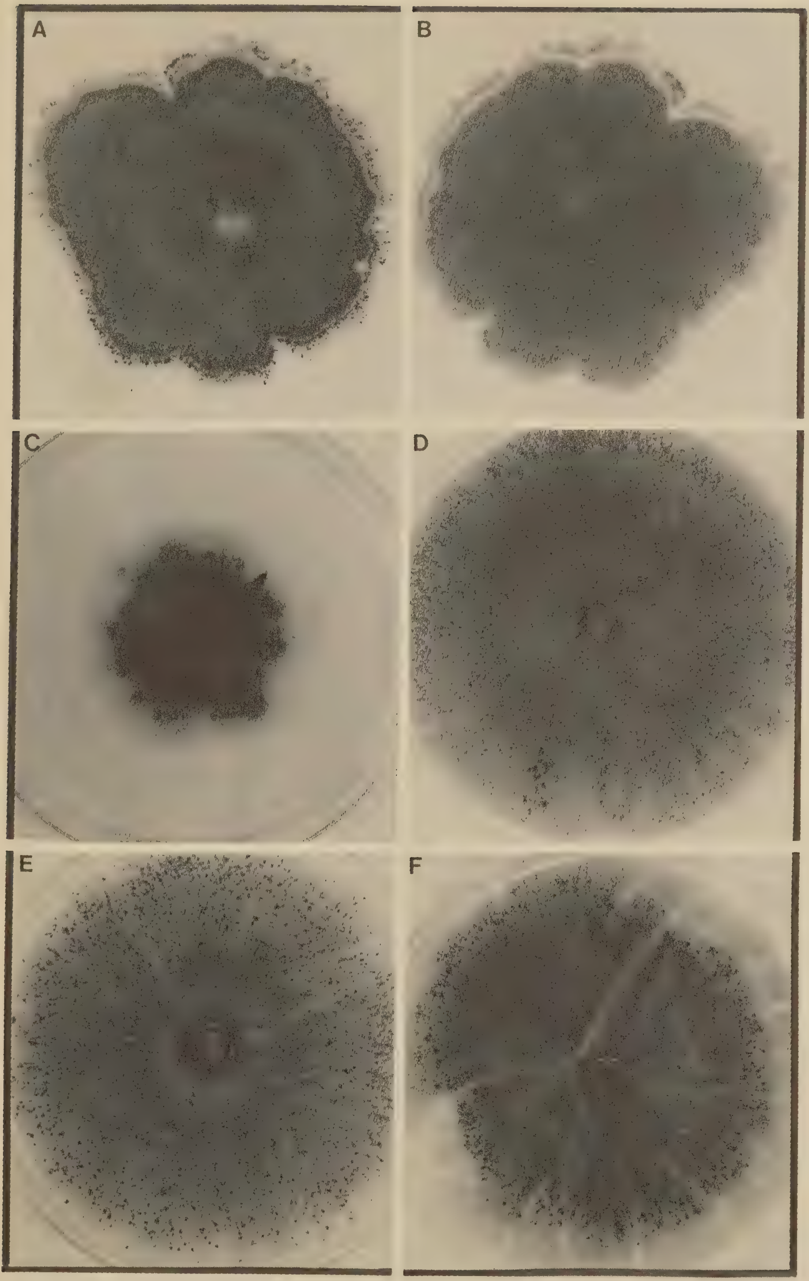
Boerema (1967) added a third variety to *P. exigua* [var. *foveata* (Foister) Boerema] when he reached the conclusion that *P. foveata* Foister, a fungus associated with gangrene of potato, was essentially similar to the former except for pigment and crystal production *in vitro*. Malcolmson (1958a) had earlier determined *P. foveata*, *P. solanicola* Prill. & Del. [= *P. exigua* var. *exigua*] and *P. tuberosa* Melhus, Rosenbaum & Schultz [= *P. exigua* var. *exigua*] to represent one species. In a separate publication (Malcolmson, 1958b), the combination *P. solanicola* f. *foveata* (Foister) Malcolmson was made. Dennis (1946) described *P. foveata*, segregating it from other *P. exigua* isolates (his group II) as his group I (strain 1). The varietal status adopted by Boerema (1967) was taken up by Logan and Khan (1969), Boyd (1972) and Sutton (1980), but Malcolmson and

Gray (1968) maintained that the differences between *P. exigua* and *P. foveata* warranted separation of the latter as a 'forma specialis', as they did in the case of *A. linicola*. Accordingly they made the combination *P. exigua* f. sp. *foveata* (Foister) Malcolmson & Gray. Logan and Khan (1969) upheld the varietal status of the *foveata* epithet on the basis of differences between it and var. *exigua* in temperature/growth relationships, pigment production and pathogenicity to potato. Boerema (1969) discussed at length the use of 'formae speciales' within the genus *Phoma*, particularly in relation to the epithets *foveata*, *linicola* and *sambuci-nigrae* (see below), and concluded that these entities can be differentiated by their combined morphological and cultural characteristics without dependence on host and pathogenicity factors. He also noted that, by adoption of the 'forma specialis' concept, they lose their official nomenclatural status and went so far as to express a preference for their maintenance as separate species rather than their demotion. Boerema (1976) reiterated the distinctions, again pointing out that categorization as 'forma specialis' was inappropriate since this suggests only pathogenicity differences. Otazū *et al.* (1979) reported the probable geographic origin of *P. exigua* var. *foveata* to be the highlands of South America. It was found parasitizing plants of *Chenopodium quinoa* Willd. in Peru, causing brown stalk rot (Boerema, 1977; Otazū and Salas, 1977; Otazū *et al.*, 1979). Boerema *et al.* (1987) in the belief that it is indigenous to the Andean region, and on the basis of differences in growth and production of anthraquinone pigments between it and *P. exigua*, reverted to the use of the binomial *P. foveata* for the potato gangrene fungus. The nomenclatural history of this entity, where the original specific epithet *foveata* has been tossed around from being a 'forma' to a 'forma specialis' to a variety and back again to a species, well illustrates the often unsatisfactory nature of infraspecific categories in the genus *Phoma*.

A fourth variety, var. *sambuci-nigrae* (Sacc.) Boerema & Höweler [≡ *Phoma herbarum* Westd. f. *sambuci-nigrae* Sacc.], was added to *P. exigua* by Boerema and Höweler (1967). It occurs on *Sambucus nigra* L. where it is associated with leaf lesions and dead shoots. It has olivaceous green colonies with even margins unlike those of var. *exigua* which are typically lobed or scalloped (Boerema, 1976). A fifth variety, var. *inoxydabilis* Boerema & Vegh, which causes leaf spots and stem blight of *Vinca* spp. and other plants, differs from var. *exigua* by showing no color reaction when NaOH is added to colonies, indicating absence of a metabolite 'E' [from *exigua*] (Boerema and Dorenbosch, 1973; Vegh *et al.*, 1974).

Popkova *et al.* (1974) proposed classifying the fungus associated with gangrene symptoms of potato in the U.S.S.R. as "*Phoma exigua* var. *solanicola* Prill. & Del.". Boerema (1976), however, has pointed out that that variety was not validly published. It was thought to be the anamorph of *Ophiobolus porphyrogonus* (Tode) Sacc. Examination of cultures obtained from K.V. Popkova, two from gangrened potatoes and two originating from a suspension of ascospores of *O. porphyrogonus*, showed them to be identical with *P. exigua* var. *exigua* (Boerema, 1976). The binomial *Leptospora rubella* (Pers.) Rabenh. was used by Boerema (1976) for the supposed teleomorph. A study by H.A. van der Aa of isolates derived from single ascospores (obtained from perithecia on

PLATE 1. *Phoma exigua* var. *exigua*. A, 14-day-old colony on PDA at 25C; B, reverse of same; C, 14-day-old colony on PDA at 20C; D, 14-day-old colony on MEA at 20C; E, 14-day-old colony on CEL at 25C; F, 14-day-old colony on CEL at 20C.


A
B
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E
F

a potato-stem piece received from K.V. Popkova) indicated cultural characteristics different from those of *P. exigua* var. *exigua* (Boerema, 1976). Perithecia, but no pycnidia, were produced *in vitro* on cornmeal agar with lupin stems at 18-24C under near ultra-violet light. There is thus some doubt concerning the suggested teleomorph / anamorph connection. *Ophiobolus porphyrogonus* was listed by Walker (1980) under *O. leptosporus* Saccas although he was uncertain, not having examined its type, of the exact identity of the latter. He noted that it probably belongs in *Leptospora* but to differ from *L. rubella* in size of asci and ascospores. Tarr (1962) had earlier commented that *O. leptosporus* was similar to *L. rubella* [as *O. porphyrogonus*] and Walker (1980) stated that it was also similar to *O. trichisporus* Ell. & Everh., a name that he and Shoemaker (1976) considered to be a synonym of *L. rubella*. According to Walker (1980), no conidial states have been found for *Leptospora* Rabenh., a genus based on *L. rubella*, to which he added *L. implexa* (Ell. & Everh.) Walker [≡ *Lophiostoma* (*Lophionema*) *implexum* Ell. & Everh.; ≡ *Ophiobolus implexus* (Ell. & Everh.) Ell. & Everh.]. *Leptospora helminthospora* Rehm, a species added to the genus in the last century, is a synonym of *Acanthophiobolus helicosporus* (Berk. & Br.) Walker.

More recently, two further varieties have been added to *P. exigua*, namely var. *diversispora* (Bubāk) Boerema [≡ *Phoma diversispora* Bubāk] and var. *lilacis* (Sacc.) Boerema [≡ *Phoma herbarum* Westd. f. *lilacis* Sacc.] (Boerema and van Kesteren, 1980; and Boerema, 1979, respectively). The former had been originally described from snap beans grown in the Italian Tirol (Bubāk and Kabāt, 1905). Reported to be a serious pathogen of *Phaseolus vulgaris* L. in Europe, it was said by Boerema *et al.* (1981), in common with var. *inoxydabilis*, to lack capacity to produce metabolite 'E' [also referred to as antibiotic 'E' (see below)]. Other differences between it and var. *exigua* included colony appearance, pycnidial and conidial characteristics when grown on low nutritional agar (Nirenberg, 1976) to which pieces of filter paper were added, as well as pathogenicity. Variety *exigua* [as *A. phaseolorum*] has also been recorded frequently on beans (e.g. by Crossan, 1958; Alcorn, 1968; and Boerema, 1972) but Boerema *et al.* (1981) suggest that at least some records in the literature (but not necessarily those cited above) of serious attacks by *A. phaseolorum* may have referred to *P. exigua* var. *diversispora*. Boerema (1972) had previously expressed the view that the European isolates named *A. phaseolorum* studied by Crossan (1958) were different from *P. exigua*. Variety *lilacis*, which causes damping off of lilac seedlings, differs appreciably from var. *exigua* in colony characteristics when grown *in vitro* and it also does not produce metabolite 'E' (Boerema, 1979).

Phoma exigua var. *exigua* is a saprophyte or a weak pathogen. Some account of its distinguishing characteristics has been given by Boerema and Höweler (1967), Dorenbosch (1970) and Laundon (1971). A description by Sutton and Waterston (1966), under the name *Ascochyta phaseolorum* Sacc., appears to be based on another fungus [conidial measurements of 13-16.5 X 3.5-5 µm are appreciably outside the range of *A. phaseolorum* (= *P. exigua* var. *exigua*)]. Saccardo (1878), in the original description of *A. phaseolorum*, gives conidial dimensions of 10 X 3 µm and these are in accordance with the currently accepted concept of var. *exigua* (Boerema, 1972). To facilitate better understanding of this entity, a comprehensive description of it *in vitro* is offered herein and an attempt is made to identify hallmark characteristics whereby it can be differentiated from other *Phoma* species.

482 30 for *A.* read *Ascochyta*

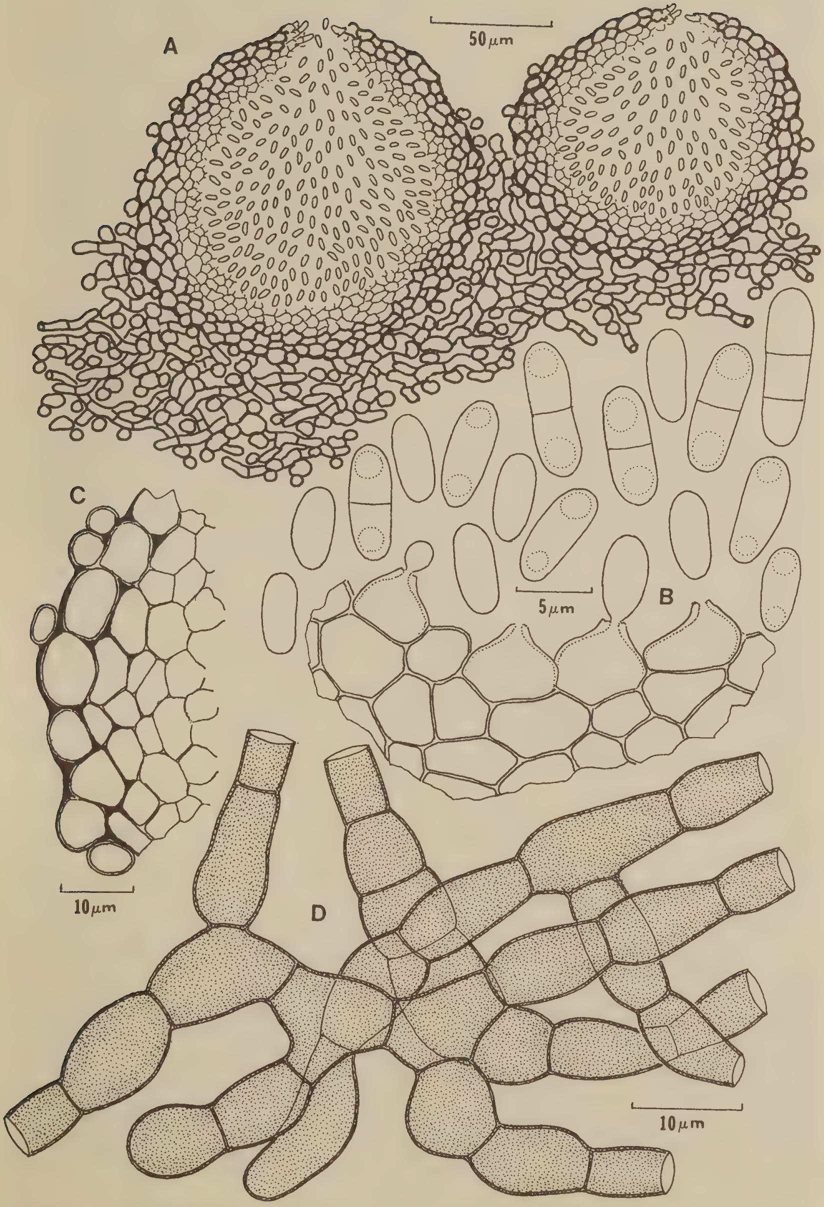
A
50 μm
B
5 μm
C
10 μm
D
10 μm

FIGURE 1. *Phoma exigua* var. *exigua*. A, V.S. pycnidia and subtending mycelial matrix; B, conidiogenous cells and conidia; C, portion of pycnidial wall in section; D, inflated hyphae.

TAXONOMIC PART

Phoma exigua Desm., *Ann. Sci. Nat.*, ser. 3, 11: 282, 1849, var. *exigua* (Plates 1 and 2, figure 1).

= *Ascochyta phaseolorum* Sacc, *Michelia* 1: 164, 1878.

= *Phoma solanicola* Prill. & Del., *Bull. Soc. mycol. Fr.* 6: 179, 1890.

= *Phoma tuberosa* Melhus, Rosenb. & Schultz, *J. Agric. Res.* 7: 251, 1916.

For additional synonyms see Boerema and Höweler (1967), Boerema and Dorenbosch (1973), and Boerema (1972, 1976).

Colonies on potato dextrose agar (PDA) [Difco] (Plate 1, A & C) variable in color and growth rate, lanose to densely felted, particularly in older cultures, irregularly lobed, ranging from white through various shades of gray to dark olivaceous-gray to blackish-brown or blackish, evenly colored or concentrically zoned with broad bands, sometimes with a whitish band alternating with darker ones, frequently with a paler margin after 7 days particularly when grown at 20C, attaining a diameter of 47-59 mm at 25C, 20 mm at 20C, with no growth at 30C; reverse black. Periphery of colonies on PDA after 14 days sometimes appearing spotted due to the production of abundant clusters of gregarious pycnidia (Plate 1, A). Colonies occasionally bear scattered, aerial, loose tufts of whitish to gray mycelium. Colonies on malt extract agar (MEA) [Difco] (Plate 1, D) dark olivaceous, mycelium mostly immersed in the form of radial strands, attaining a diameter after 7 days of 58 mm at 25C, 70 mm at 20C, with no growth at 30C. Colonies on cellulose agar thin, with little aerial mycelium, pale gray olivaceous, producing abundant pycnidia after 14 days (Plate 1, E & F). Mycelium composed of hyphae of two types; hyaline to subhyaline, thin-walled, smooth, sparsely branched, straight or slightly flexuous, 3-4 µm wide; and pale to mid brown, thicker-walled, smooth, abundantly branched, straight, flexuous or contorted, 4-8 µm wide. The latter type frequently with individual cellular elements inflated to 15 µm wide (Figure 1,D) and somewhat chlamydospore-like, but not thicker-walled where swollen, constricted at the septa, aggregated and interweaving, especially in the vicinity of pycnidial clusters to form loose, stroma-like masses or mounds subtending the conidiomata (Figure 1, A). In older colonies on PDA abundant development of such hyphae results in blackish coloration. Pycnidia produced abundantly on PDA, MEA and cellulose agar, maturing less readily on MEA, scattered or, more frequently, gregarious in clusters of several, sometimes confluent but mostly maintaining discrete venters, more or less globose to subglobose, superficial or partly immersed, inconspicuously ostiolate, brown to black with age, 110-160 µm in diameter. Pycnidial wall (Figure 1,C; Plate 2, C & D) made up of five to seven layers of cells; consisting of an outer zone, two layers thick, of isodiametric to ellipsoid, thick-walled, pigmented cells, sometimes rather loosely organized with interweaving hyphal elements discernible in surface view, and an inner zone, three to five layers thick, of more or less isodiametric, angular, thin-walled, subhyaline cells. Accumulations of brown, non-granular, extra-cellular deposits present between cells of the outer zone and on the exposed surface. Ostiole inconspicuous, discrete, lined with papillate, subhyaline cells. Conidiogenous cells phialidic, hyaline, simple, smooth, ampulliform, with a thickened periclinal wall, borne on pycnidial wall cells lining the venter. Conidia enteroblastic, somewhat variable in shape and size, hyaline, smooth, oblong to ellipsoid or narrowly obovoid, straight or very slightly

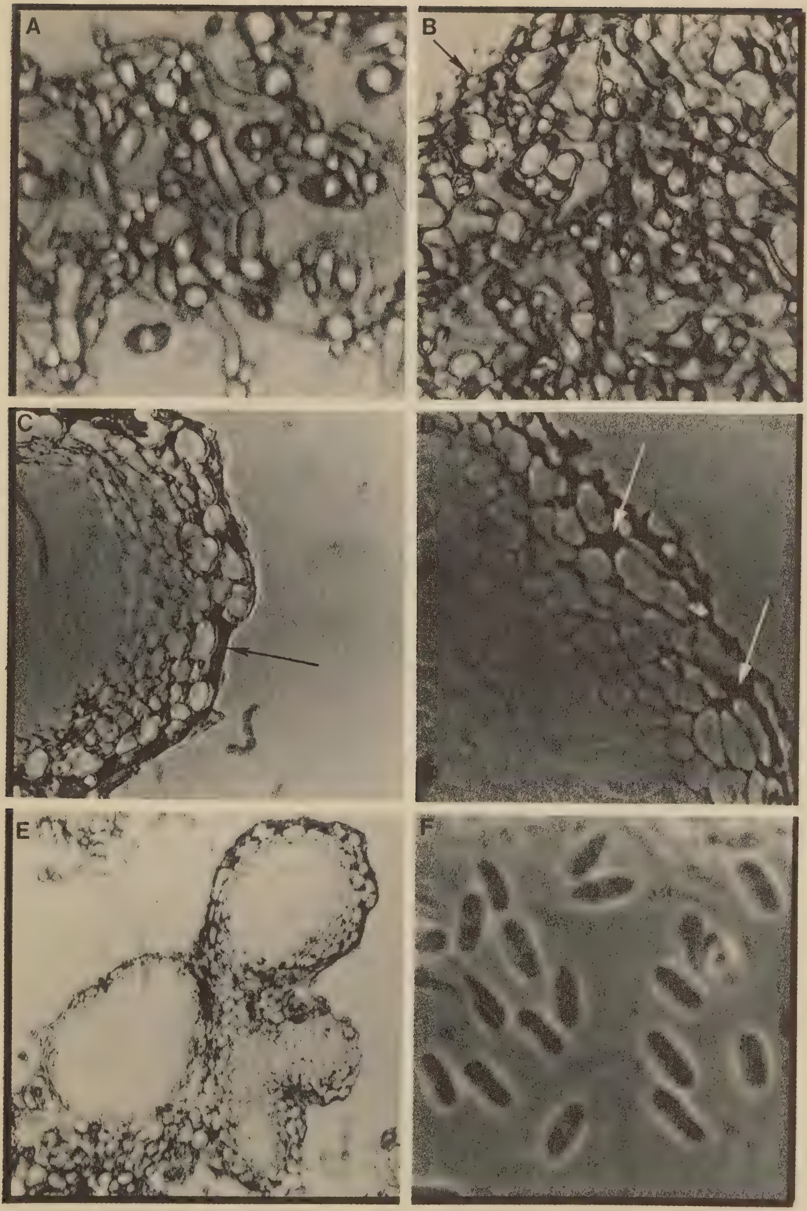

PLATE 2. *Phoma exigua* var. *exigua*. A & B, sections of mycelial matrix in young and older colonies, respectively (pycnidial wall indicated by arrow in B); C & D, sections of pycnidial walls showing extra-cellular deposits (indicated by arrows); E, section of pycnidial cluster; F, conidia.

curved, often biguttulate, unicellular or becoming 1-septate, very occasionally 2-septate, 4-12 X 2.5-3.5 µm.

Ubiquitous; cosmopolitan.

Collection examined: isolated from tuber of *Solanum tuberosum* L., The Netherlands, G.H. Boerema PD 75/97, ATCC 28980 [representative culture, fide Boerema (1976)].

DISCUSSION

Phoma exigua var. *exigua* possesses a number of characteristics by which it can easily be distinguished from other taxa. Although colonies derived from single conidia can be somewhat variable *in vitro* on PDA and other media, particularly in coloration and in amount of aerial mycelium produced, a strong tendency for their periphery to be appreciably lobed or scalloped is a distinctive feature (Plate 1, A; see also illustration in Dorenbosch, 1970). This results from a few lead hyphae along the colony margin assuming growth dominance. In colonies on cellulose agar (Plate 1, F), each marginal lobe has a fan-shaped appearance. Some isolates, considered to be the more typical, have prominently lobed colonies while others have colonies with less deep marginal indentations. With the production of pycnidial clusters, the overall effect of the unequal radial growth pattern is to give colonies, as aptly described by Laundon (1971), a "rather dirty, irregular and bedraggled appearance". When grown at 20C, colonies frequently have a broad, white marginal zone but their margins are not as deeply lobed as at 25C. The scattered tufts of inflated pale brown hyphae associated with pycnidial clusters and eventual formation, in older colonies, of a matrix of tightly interwoven hyphal elements below and around the conidiomata is another feature useful in recognizing var. *exigua*.

The anatomy of the pycnidial wall of *P. exigua* var. *exigua* is also distinctive, as it is in the other species of *Phoma* described previously in this series of papers. Although only sporadic attention has been paid in the past to this criterion, it can be an important differentiating characteristic between species. In our experience and that of Morgan-Jones and White (1987a), the pycnidial wall anatomies of individual species are discernibly different. Morgan-Jones and White (1987a) recognized four reasonably distinct wall texture types within the genus *Phoma* as presently constituted. They reported, following examination of over thirty species, considerable diversity in cell shape, pigmentation, wall thickness and organization to exist among different taxa. It is evident that the use of loosely descriptive terms, such as "prosenchymatous", "pseudoparenchymatous", "pseudosclerenchymatous" and "scleroplectenchymatous", in the literature, in reference to pycnidial conidiomata, does not adequately document important differences. In some pycnidia, pigmented, extracellular deposits are present between outer wall cells. Such is the case in *Phoma glomerata*(Corda) Wollenw. & Hochapfel (White and Morgan-Jones, 1987), where the deposits have a somewhat granular texture. Similar material occurs in the pycnidial walls of the *Fusicoccum* state of *Botryosphaeria ribis* Grossenb. & Duggar (Morgan-Jones and White, 1987b). We are also aware of the occurrence of pigmented extracellular substance in the walls of *Pleurophoma pleurospora* (Sacc.) Höhnel and brown, melanin deposits are present around and in-between outer wall cells in older pycnidia of *P. herbarum* and *P. terrestris* Hansen (unpublished data). The presence of such inclusions in *P. exigua* var. *exigua* is an additional characteristic by which the taxon can be distinguished.

Boerema and Höweler (1967) reported synthesis of a colorless metabolite [variously referred to as metabolite 'E' or substance E] by *P. exigua* and several other *Phoma* species. The metabolite was said to be easily oxidized to a pigment 'α' and a pigment 'β' successively. Production was found to be stimulated by daylight and to vary according to agar medium on which colonies were grown and medium pH. The presence of this substance can be demonstrated by adding a drop of concentrated NaOH to the margin of colonies on malt agar which produces an initial blue-green color reaction, turning to brownish-red (Dorenbosch, 1970; Boerema and Dorenbosch, 1973). Pigment 'α' is blue-green at pH < 12.5 and pigment 'β' is red at pH > 5.5 (Boerema, 1976). Logan and O'Neill (1970) showed the metabolite to have bactericidal and fungicidal properties and, as a result, referred to it as "antibiotic 'E'". In combination with other characteristics, presence of this substance seems an useful diagnostic feature but, as Dorenbosch (1970) has pointed out, not all isolates show a strong color reaction. Metabolite 'E' is not, as mentioned above, produced by all presently accepted varieties of *P. exigua*. Some isolates of *P. foveata* produce the substance and appear to be more pathogenic to potato than isolates that do not (Logan and Woodward, 1971; Rogers and Stewart, 1974). Both *P. exigua* var. *exigua* and var. *inoxydabilis* have been reported to produce cytochalasin B (Bousquet and Barbier, 1972; Scott *et al.*, 1975).

Phoma exigua var. *exigua* can be distinguished from *P. herbarum*, with which it has sometimes been confused in the past on host material, in a number of respects. *Phoma herbarum*, which is much less common on herbaceous stems than *P. exigua* (Boerema and Höweler, 1967), has substantially smaller, unicellular, eguttulate conidia (Boerema, 1964; Sutton, 1964; Sutton, 1980). Colonies of the two species are quite different *in vitro*. Those of *P. herbarum* on PDA are generally grayish to olivaceous-green in color, with sparse aerial mycelium, an invariably even margin, and are appreciably slower growing. Colonies of that species also usually produce some reddish-purple discoloration of the medium which turns blue upon application of NaOH (Dorenbosch, 1970). Both *P. lycopersici* and *P. exigua* var. *exigua* are known to be associated with stem and fruit rot of tomato (Laundon, 1971) and both produce conidia that become medianly one-septate. They can, however, be readily differentiated by colony characteristics, production of sterile "stilboid bodies" and absence of metabolite 'E' [negative NaOH test] in the former, and by conidiomatal morphology (cf. Morgan-Jones and Burch, 1988).

Although considered a weak pathogen *P. exigua* var. *exigua* is often associated with distinct disease symptoms such as leaf lesions and dieback (Boerema, 1976). On decaying organic matter near the surface of soil it is one of the most frequenly found pycnidial fungi (Domsch *et al.*, 1980). There are also a number of reports of its occurrence in soil (e.g. by Gams *et al.*, 1969; Tiwari and Agrawal, 1972; and Youssef, 1974). Kondakova (1976) reported finding it colonizing cysts of the potato cyst nematode *Globodera rostochiensis* (Wollenw.) Stone.

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PEZICULA TASMANICA: PHYLLOCLADICOLOUS, NOT FOLIICOLOUS

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We described the new species *Pezicula tasmanica* Zhuang & Korf (**1988**) as occurring on "leaves of *Phyllocladus aspleniifolius* in Tasmania." Our friend and colleague, Professor William I. Illman, recently retired from Carleton University in Ottawa and currently at the Biosystematics Research Institute, Central Experimental Farm, Ottawa, has very gently reminded us that *Phyllocladus* (variously assigned to the Coniferae, Podocarpaceae, or most recently to the Phyllocladaceae) is characterized by its lack of leaves, and by the formation of phylloclades (alternatively, cladodes), modified leaf-like *branches* with photosynthetic function. Our characterization of the new species as being foliicolous was thus wholly false, as it occurs instead on the phylloclades.

Indeed, the genus *Pezicula* is so characteristically wood-inhabiting and bark-inhabiting, most frequently on branches of various angiosperms and gymnosperms (and also on canes of *Rubus*), that at first we strongly resisted placing the new species in *Pezicula,* despite its clear resemblance in microanatomy to other species of the genus. We later concluded that since "The leaves of *Phyllocladus* are exceptionally tough and rigid" we would nonetheless place the species there, on a substrate (leaves) new for the fungal genus. Obviously Peziculas are better morphologists than we: *Pezicula tasmanica* knows it ought not to occur on leaves, and should be on branches. Our misidentified "leaves" are branches after all!

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BOOK REVIEWS

by

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THE FIFTH KINGDOM, by KENDRICK, B., vii+363 p., ill., 15 x 22 cm, paperback, 1985. Mycologue Publications, 331 Daleview Pl., Waterloo, Ontario N2L 5M5, Canada. ISBN 0-9692237-0-6.

Dès la première page qu'illustrent deux jeunes crapauds émergeant d'un carpophore discoïde de "toadstool", le Professeur Kendrick éveille la curiosité du lecteur et développe tout au long du livre son intérêt pour ce monde nouveau qu'est le règne des champignons.

Ce règne, le cinquième mais pas le moindre puisqu'il est maintenant reconnu à la suite de Whittaker à l'égal de ceux des plantes et des animaux, il en explore les facettes les plus étranges, les plus caractéristiques aussi, conduisant son lecteur au travers de toute la mycologie. De la taxonomie à la nutrition, de la symbiose à la pathogenèse, de la toxicité à la comestibilité, des activités fermentaires à la compétitivité biologique, des hallucinogènes aux mycoses, tous ces chemins, marqués d'un vocabulaire nouveau mais bien défini, sont faciles à parcourir au travers des 23 chapitres du cours. Il mènent à un bon aperçu de ce monde fascinant, et de sa relation avec les autres êtres vivants et l'homme. Documenté de références bibliographiques, ce livre permet d'aborder des ouvrages plus approfondis. Il est aussi d'une lecture agréable qui ne peut déplaire à aucun débutant. Aussi peut-on recommander son usage à tout enseignant de la mycologie au premier niveau et à toute personne curieuse d'explorer un autre monde.

NEW OR CRITICAL HYPHOMYCETES FROM INDIA, by RAO, V. and G.S. DE HOOG, Studies in Mycology n° 28, 84 p., 34 fig., 16 x 24 cm, paperback, 1986. Centraalbureau voor Schimmelcultures, P.O. Box 273, 3740 AG Baarn, The Netherlands. ISBN 90-70351-11-0 CIP.

The senior author, a known mycologist from Hyderabad, India, collected leaf litter and rotten wood Hyphomycetes for almost twenty years in South, Central and East India.

A selection of thirty-two taxa including twenty new species, are described in *Brachydesmiella, Monotosporella, Dendryphiosphaera, Cheiromyces, Monodictys, Hermatomyces, Leptodontidium, Ramichloridium, Spadicoides, Cordana, Exserticlava, Vermispora, Haplographium, Menisporiopsis, Craspedodidymum, Bahusutrabeeja, Cyrithrix* and *Helminthosporium*, a new variety in *Brachydesmiella biseptata* and two combinations in *Monodictys.*

The publication is also interesting for the quality of Vasant Rao's drawings of these peculiar and uncommon fungi, most from natural substrate in the tropics, some from pure culture. A few species are described in their various synanamorphs, as are *Ramichloridium fasciculatum, Cordana solitaria.* The ontogeny of bulbilous dictyoconidia like those of *Berkleasmium, Dictyosporium, Cheiromyces, Pithomyces, Monodictys, Hermatomyces,* is carefully observed. Type material is preserved in CBS herbarium at Baarn, together with

material of 55 other identified taxa listed at the end of the paper, collected from similar localities.

A REVISION OF THE GENUS GEOTRICHUM AND ITS TELEOMORPHS, by DE HOOG, G.S., M.Th. SMITH and E. GUEHO, Studies in Mycology n°29, 131 pp., 32 fig., paperback, 16 x 24 cm, 1986. Centraalbureau voor Schimmelcultures, P.O. Box 273, 3740 AG Baarn, The Netherlands. ISBN 90-70351-13-7. Hfl 45.-

This excellent monograph of *Geotrichum* includes twenty-three taxa, fourteen as anamorphs of *Dipodascus* species, two of *Galactomyces*. One hundred ninety-two names from these genera and *Endomyces* have been critically revised.

The taxonomic treatment integrates morphology, physiology and DNA base composition. DNA-DNA reassociation data have been acquired but proved to be of less taxonomic value. Selected physiological characteristics are used as key characters: growth responses to xylose, sucrose, raffinose, cellobiose, sorbitol, D-manitol, D-glucitol, D-glucono-d-lactose, salicin, arbutin, citrate, absence of vitamin and temperature 37° versus 40°C. Many more have been investigated and are recorded. A few species, *Geotrichum fermentans, G. klebahnii, G. fragrans*, are fermentative on D-glucose and D-galactose.

Geotrichum is characterized by serial arthroconidia that often originate from typical sympodial branching, but some species are pleoanamorphic. *Geotrichum fermentans* produces also blastoconidia in clusters. *Dipodascus ambiosiae* and *G. fragrans* show repetitive percurrent growth of arthroconidia. *Dipodascus capitatus* produces endoconidia in hyphae and secondary sympodial conidia. From 29 strains of *Galactomyces geotrichum (Geotrichum candidum)*, twelve strains are heterothallic bipolar and four strains are homothallic. The investigated characteristics indicated the possible existence of two groups in the species, but without sufficient consistency; also, members from both groups would be interfertile.

The identification of *Geotrichum* species and of their teleomorphs is no longer possible on herbarium material. The correct recognition of *Geotrichum* species must be made on pure cultures.

CBS COURSE OF MYCOLOGY, by GAMS, W., H.A. VAN DER AA, A.J. VAN DER PLAATS-NITERINK, R.A. SAMSON and J.A. STALPERS, 137 pp., 74 fig., 17 x 24 cm, cloth hardcover, 1987. Centraalbureau voor Schimmelcultures, P.O. Box 273, 3740 AG Baarn, The Netherlands. ISBN 90-70351-12-9 GEB.

This third edition is fully updated. The first part provides with the techniques for the study of fungi: isolation, microscopy and preservation in culture and in herbarium. A short introduction to the fungal system and its nomenclature is given. The main part deals with a didactic description of the classes of Fungi, with good terminology and many illustrations. The illustrations are mostly well-reproduced from other sources. Only the one of *Phytophthora infestans* (fig. 18A) is very inaccurate and inadequate. The references to literature have been largely expanded. The course is a good and easy introduction to the fungi, especially as a support to demonstration sessions in the field and at the laboratory.

ADVANCES IN PENICILLIUM AND ASPERGILLUS SYSTEMATICS, by SAMSON, R.A. and J.I. PITT, Ed., Series A: Life Sciences, Vol. 2, x+484 p., ill., 16 x 25 cm, cloth hardcover, 1985. Plenum Publishing Corporation, 233 Spring Street, New York, NY 10013, U.S.A. ISBN 0-306-42222-0. US $85.- (U.S.A., Canada), $102.- (elsewhere).

Several monographs or revisions of the genus *Penicillium* appeared in the last decades and demonstrated a lack of agreement in the taxonomy of the group. Species descriptions need a more consistent terminology and a true evaluation of the variability of morphological criteria. New characteristics are also being investigated to evaluate their potential use in taxonomy as well as to test the morphologically based taxonomy. Similar efforts are also brought in the taxonomy of *Aspergillus*.

This book contributes thirty-four papers from a large panel of specialists. Some contributers analyse critically the actual descriptive terminology and methodology, and claim for better standardization. Several contributers also explore new characteristics of these fungi with taxonomic purposes: nucleic acid relatedness, immunological reactions, profile of primary and secondary metabolites, protoplast hybridization, scanning electron microscopy of spores and conidia. A paper like the one by the CMI mycologists reports research progress towards a reappraisal of morphological criteria and the edification of a more comprehensive taxonomy. The authors investigated new criteria such as enzymatic activities and secondary metabolites.

Morphology is however not left aside. A new scheme of infrageneric subdivision base on conidiophore branching, on shape of phialides and on shape and ornamentation of conidia is proposed for *Penicillium* by Stolk and Samson. A new key to the subgenus *Penicillium* is offered by Pitt and Williams. The relationship of teleomorphic *Penicillium* and *Aspergillus* with the other Ascomycetes and the connection teleomorph-anamorph have received full attention.

The book, editing the proceedings of a NATO workshop held in Amsterdam in May 1985, is a milestone on the long way to a better definition of the *Penicillium* and *Aspergillus* taxa and stabilization of their nomenclature.

PLEOMORPHIC FUNGI: the Diversity and Its Taxonomic Implications, by SUGIYAMA, J., xv+325 p., ill., 15 x 22 cm, cloth hardcover, 1987. Elsevier Science Publishers, 25 Sara Burgerhartstraat, P.O. Box 211, 1000 AE Amsterdam, The Netherlands. ISBN 0-444-98966-8. US $111.-, Dfl. 250.-

Most fungi are pleomorphic, producing a diversity of reproductive cells. From Tulasne up to the present days, an increasing number of publications have pointed out pleomorphism in the field and in culture and demonstrated the connections between teleomorphs and anamorphs or between synanamorphs. It cannot be ignored therefore in a fungal taxonomy based on reproduction, which conidium or spore ontogeny is a major criterium of recognition.

The book results from a symposium convened by the author at the 1983 third International Mycological Congress in Tokyo.

The purpose of the Symposium is to contribute updated knowledge and better understanding of pleomorphic and pleoanamorphic fungi, and to indicate implications of pleomorphism in taxonomy and nomenclature of the fungi.

Important contributions describe the diversity of reproductive forms in the Hypocreales (Samuels and Seifert), the Sordariales (Lodha), the Halosphaeriaceae (Nakagiri and Tubaki), the hyphopodiate Ascomycetes (Hughes), the sooty moulds (Sugiyama and Amano), the plant pathogenic Ascomycetes (Tsuda and Ueyamo), the Holobasidiomycetes (Stalpers), the yeast-like Hyphomycetes (de Hoog), the helicosporous Hyphomycetes (Goos) and their geographical distributions.

The plasticity of conidiogenesis is made a significant feature of pleoanamorphy by Minter, that must be considered as such in the taxonomy of the whole fungus rather than as a basis for the discrimination of different patterns of conidial ontogeny, and consequently of several anamorphs. Nomenclatural implications of such pleoanamorphy are also investigated up to their extreme ends and lead to the same conclusion.

The book is, after Kendrick's *Taxonomy of Fungi Imperfecti* and *The Whole Fungus*, another step ahead towards a more comprehensive knowledge of the pleomorphic fungus.

CHESNUT BLIGHT, OTHER ENDOTHIA DISEASES, AND THE GENUS ENDOTHIA, by ROANE, Martha K., Gary J. GRIFFIN and John R. ELKINS, APS Phytopathological Monograph Series, 53 pp., 34 fig., 20 x 26 cm, paperback, 1986. The American Phytopathological Society, 3340 Pilot Knob Road, St Paul, Minnesota 55121, U.S.A. ISBN 0-89054-073-X. US $12.- (APS member), $15.-(non-member).

This monograph is the ninth one of the series and is devoted to *Endothia* diseases. The first part deals with the chestnut blight and its causal agent, *Endothia parasitica*. Virulent strains of the fungus have almost destroyed the American chestnut, while hypovirulent strains saved the European chestnut. Comparative biological and phytopathological studies of both virulent and hypovirulent strains, and of the mycovirus associated with the latter, led to the transmission of the hypovirulence genes to the virulent strains and the obtaining of biological control of the disease. Enhancing chestnut resistance to blight by using Chinese clones in selection is another promising way of control. Other diseases caused by *Endothia* species are also revised (Part II).

In Part III, Martha K. Roane proposes an interesting monographic treatment of the genus *Endothia* based on a critical study of one hundred collections and literature. The name *Endothia* is revealed to be not a teleomorphic but an anamorphic name by type. However the author uses it as teleomorphic and proposes that it should be conserved as such. Barr's treatment of *Endothia* based on stromatic tissue organization is no longer accepted. Orsenigo's subdivisions of the genus are adopted but both subgeneric names *Proendothia* and *Euendothia* are invalid. The genus divides into two sections, one with cylindric or allantoid nonseptate ascospores for the type *E. gyrosa* and 2 species, the other with fusiform one-septate ascospores including 7 species. The taxa are described and keyed out. Eight anamorphic names are created in *Endothiella*. Eight taxa are excluded from *Endothia*, seven regarded as doubtful. *Endothia* is reclassified in the Diaporthaceae.

In the last part dealing with physiology of *Endothia*, the author discusses environmental and nutritional factors at one side and the secondary metabolite production like pigments and aroma at the other side. 268 references to literature document this valuable monograph.

COMPENDIUM OF BEET DISEASES AND INSECTS, by WHITNEY, E.D. and J.E. DUFFUS, 76 pp., 36 fog., 243 col. ph., 21 x 28 cm, paperback, 1986. The American Phytopathological Society, 3340 Pilot Knob Road, St. Paul, Minnesota 55121, U.S.A. ISBN 0-89054-070-5. US $17.- (member), $20 (non-member).

Ce quatorzième Disease Compendium of the American Phytopathological Society concerne l'espèce *Beta vulgaris* sous toutes ses variétés cultivées: la betterave sucrière, la betterave fourragère, la betterave rouge, la bette et d'autres. Sur le même schéma que les Compendiums précédents, il étudie (Part I) les maladies biotiques, d'abord les maladies d'origine fongique des semis (*Aphanomyces, Pythium*, *Rhizoctoria*) et celles des feuilles et des racines, ensuite les maladies bactériennes et virales et les dégâts par nématodes.

Dans la partie II, les insectes, spécialement les aphides, et les arthropodes sont passés en revue. La partie III couvre les désordres abiotiques parmi lesquels les déficiences minérales et les dégâts climatiques. Ce Compendium est particulièrement bien illustré de 243 photos couleurs et de nombreuses photos blanc-noir et dessins. Les descriptions sont suffisantes pour orienter efficacement l'identification des champignons et autres agents phytopathogènes.

COMPENDIUM OF RHODODENDRON AND AZALEA DISEASES, by COYIER, D.L. and M.K. ROANE, vii+65 pp., 12 fig., 80 col. ph., 21.5 cm x 28 cm, paperback, 1986. The American Phytopathological Society , 3340 Pilot Knob Road, St. Paul, Minnesota 55121, U.S.A. ISBN 0-89054-075-6. US $15.- (APS member), $20.- (non member).

Ce Compendium sur les Rhododendrons et Azalées est destiné non seulement aux scientifiques mais aussi aux spécialistes de l'horticulture, pépiniéristes et amateurs. Il constitue un des rares ouvrages qui existent sur la pathologie de ces plantes ornementales. Le genre *Rhododendron* incluant les Azalées comprend plus de 70 espèces dont 17 sont cultivées. Nombreuses sont les maladies fongiques. Les principales sont dues aux *Phytophthora* (12 espèces), à *Armillariella*, *Phymatotrichopsis*, *Cylindrocladium*, *Exobasidium*, *Ovulinia* et aux rouilles du genre *Chrysomyxa*. Des insectes coléoptères causent aussi d'importants dégâts, de même la pollution de l'air par des agents chimiques auxquels ces plantes sont particulièrement sensibles. Des index et de nombreuses illustrations aideront une première identification rapide des agents pathogènes.

COMPENDIUM OF SORGHUM DISEASE, by FREDERIKSEN, R.A., 82 pp., 44 fig., 118 col. ph., 22 x 28 cm, paperback, 1986. The American Phytopathological Society, 3340 Pilot Knob Road, St Paul, Minnesota 55121, U.S.A. ISBN 0-89054-069-1. US $15.- (APS member), $20.- (non member).

Ce Compendium sur le Sorgho (*Sorghum bicolor*) intéressera les régions tempérées chaudes autant que les subtropicales et tropicales. Les maladies du Sorgho les plus nombreuses sont celles des feuilles, dues aux champignons *Exserohilum*, *Colletotrichum*, *Gloeocercospora*, *Ramulispora*, *Acremonium*, les mildious. Sur les épis, les charbons, *Sporisporium reilianum* et *S. sorghi* sont d'importants pathogènes. Les *Fusarium* attaquent surtout les tiges et les racines. Les virus sont ceux aussi de la canne à sucre. Après les maladies biotiques et les dégâts abiotiques, les auteurs n'ont pas omis de considérer les champignons endomycorhizogènes, *Gigaspora*, *Glomus* et autres dont le sorgho bénéficie. 118 illustrations en couleurs des symptômes pathologiques rendent ce compendium aisément utilisable.

COMPENDIUM OF ORNAMENTAL FOLIAGE PLANT DISEASES, by CHASE, A. R., 92 p., 69 fig., 133 col. ph., 21 x 28 cm, paperback, 1987. The American Phytopathological Society, 3340 Pilot Knob Road, St Paul, Minnesota 55121, U.S.A. ISBN 0-89054-077-2. US $20.- (U.S.A.), $25.- (elsewhere).

La diversité des 38 espèces de plantes à feuillage ornementales appartenant à 8 familles végétales fait de ce 17ème Compendium de leurs maladies un répertoire plutôt qu'une monographie détaillée. Les maladies fongiques de ces plantes sont très nombreuses et diversifiées. Plusieurs sont propres à la culture en serre. Les champignons phytopathogènes considérés appartiennnent à *Acremonium, Alternaria, Aspergillus, Botrytis, Calonectria, Ceratocystis, Cercospora, Colletotrichum, Coniothyrium, Corynespora, Curvularia, Cylindrocladium, Cytosporina, Dactylaria, Fusarium, Gliocladium, Helminthosporium, Exserohilum, Drechslera, Kutilakesa, Leptosphaeria, Myrothecium, Pestalotiopsis, Phomopsis, Phytophthora, Pythium, Rhizoctonia, Sclerotinia, Sclerotium, Rhizopus, Stemphylium, Verticillium.* Les maladies bactériennes et virales ne sont pas moins nombreuses.Très utilement, une illustration de plus de 200 photos illustre ce guide.

COMPENDIUM OF WHEAT DISEASE, Second Edition , by WIESE, M.V., viii + 112 p., 115 fig., 74 col. ph., 21 x 28 cm, paperback, 1987. The American Phytopathological Society, 3340 Pilot Knob Road, St Paul, Minnesota 55121, U.S.A. ISBN 0-89054-076-4. US $20.- (APS member), $25.- (non member).

Cette deuxième édition du Compendium sur les maladies du froment remet à jour la description des symptômes et des agents pathogènes dans plus de 44 maladies fongiques, 10 attaques par nématodes, 33 symptômes viraux et de nombreux désordes abiotiques. Les champignons *Claviceps purpurea*, *Microdochium nivale,* plusieurs *Fusarium*, des

Alternaria, Ascochyta, Colletotrichum, Bipolaris, Dilophospora, Oïdium, Septoria, Sclerotinia, Platyspora, Puccinia, Tilletia, Ustilago, Sclerophthora, et sur les racines, *Rhizoctonia, Gauemannomyces, Pythium* et *Polymyxa*, pour ne citer que les principaux. Tous sont décrits de manière documentée avec symptômes et cycles épidémiologiques. L'illustration de cette édition est portée à 190 photos et dessins.

A LITERATURE GUIDE FOR THE IDENTIFICATION OF PLANT PATHOGENIC FUNGI, by ROSSMAN, A.Y., Mary E. PALM and Linda J. SPIELMAN, 252 p., 14 x 21 cm, paperback, 1987. The American Phytopathological Society, 3340 Pilot Knob Road, St. Paul, Minnesota 55121, U.S.A. ISBN 0-89054-080-2. US $24.- (U.S.A.), US $30.- (elsewhere).

This pocket size guide to the literature will prove very helpful to many plant pathologists and mycologists in locating sources of descriptions, illustrations, diagnoses of plant pathogenic fungi and basic information on the diseases. The literature on the major taxonomic groups, classes and orders, to which plant pathogenic fungi belong, makes a first list. Pertinent literature on the genera and their species follows in the alphabetical order of the generic names. Key words and comments are added to the references under most generic names, pointing out particular pathogenic species and their hosts or divergent taxonomic positions or nomenclatures of species. The guide ends with an author index and a host index. It is, without doubt, a very needed tool.

DIAGNOSE-METHODEN, by WETZEL T., in Diagnose von Krankheiten und Beschädigungen an Kulturpflanzen, edited by Spaar, D., Kleinhempel, H. and Fritzsche, R., 198 pp., 103 fig., 24 x 17 cm, cloth hardcover, 1984. Springer Verlag, Heidelberger Platz 3, D-1000 Berlin. ISBN 3-540-13313-5. DM 59.-, US $21.50.

Often, plant pathologists need using a wide range of techniques in order to assess the true cause of a disease. Those techniques must be applied from the sampling of diseased material to the demonstration of the effectiveness of the suspected cause. This handbook provides an overview of the most available methods in the identification of a disease or injury causal agent, either abiotic or biotic, viruses, mycoplasms, bacteria, fungi, nematodes, insects or mites. In the chapter about fungi, the proposed methods are classical ones. They concern the direct examination of the pathogen on the host or after isolation and culture in vitro, the detection of pathogens in seeds or in soil, the production of monospore culture, spore mass or suspension and calibrated inoculum and the testing of fungal pathogenicity in vitro and in the field.

GEMÜSE, by SPAAR, D., H. KLEINHEMPEL and R. FRITZSCHE, in Diagnose von Krankheiten und Beschädigungen an Kulturpflanzen, edited by the same, 406 p., 15l col. pl., 67 fig., 24 x 17 cm, cloth hardcover, 1986. Springer Verlag, Heidelberger Platz 3, D-1000 Berlin. Germany. ISBN 3-540-13314-3. DM 140.-

A picture book that may help rapid identification of common diseases and injuries in over 30 cultivated vegetables. Amongst those, edible *Agaricus* is considered. 151 types of disease and injury are illustrated in full pages facing with a description. Symptoms on host plant and animal agents are represented in color. On the forty plates illustrating fungal diseases, microscopic features of the pathogenic fungi are drawn coarsely and the fungus is not described. Keys based on symptoms are provided for each of the 18 groups of vegetables, that lead to the identification of more diseases or injuries than those illustrated. The edition is of quality. The book will surely be useful to fieldmen.

THE BIOLOGY OF YEAST , by BERRY, D.R., Studies in Biology n° 140, 60 p., ill., 144 x 22 cm, paperback, 1982. Edward Arnold Publ., 41 Bedford Square, London WC1 3DQ, UK. ISBN 0-7131-2838-0. £ 3.25.-

La levure de boulangerie, *Saccharomyces cerevisiae*, est la seule espèce considérée dans ce petit fascicule sous ses différents aspects cellulaires: la structure cellulaire, la nutrition, le métabolisme, le génome, les enzymes, la croissance et la division, les biosynthèses, la reproduction sexuelle, l'hérédité et les manipulations du génome. Ces aspects prennent alors tous un sens pratique lorsque le lecteur découvre leur application dans l'usage industriel de la levure, dans les fermentations boulangères, les fermentations alcooliques, les productions de biomasse, d'autolysats et d'enzymes. Ce livre, par ailleurs économique, est destiné aux étudiants.

A CLINICIAN'S GUIDE TO FUNGAL DISEASE, by ROBERTS, S.O.B., R.J. HAY and D.W.R. MACKENZIE, 252 p., ill., 15 x 23 cm, cloth hardcover, 1984. Marcel Dekker, Inc., P.O. Box 5005, Cimarron Road, Monticello NY 12701, U.S.A. ISBN 0-8247-7170-7. US $59.50.-

Young medical graduates are ill-prepared to approach and diagnose human mycoses. They are also confused by the profusion of mycological terms and by the frequency of change of the fungal names. The authors of this book succeeded in providing clinicians and students with brief, readable information on diseases caused by fungi, to give the laboratory workers a clearer understanding of fungal diagnosis and to show that laboratory and research work on human mycoses may best serve both physisians and patients. After an introduction to fungi and fungal ecology, the authors consider the superficial mycoses, the subcutaneous ones, the systemic ones, the oculomycoses, the otomycoses, the allergies to fungi, the mycotoxicoses and the symptoms of other possible fungal infections successively. In each pathogeny, the causal organism, its epidemiology, pathogenicity, occurrence, sites, symptoms are described. Ways of laboratory diagnosis (microscopy, histology, culture, ecology) and ways of therapy are also given. At the end of the book, treatment principles and properties of drugs such as polyenes, flucytosine, imidazole, griseofulvin, are detailed. This book, briefly said, gives everything the clinician needs to know for a professional approach of the human mycoses.

CLE DE DETERMINATION MACROSCOPIQUE DES CHAMPIGNONS SUPERIEURS DES REGIONS DU NORD DE LA FRANCE, by COURTECUISSE, R., 473 p., 392 fig., 16 x 23 cm, paperback, 1986. Société Mycologique du Nord, 109 Bd. de Fourmies, 59100 Roubaix, France.

The more mushroom species a flora describes and from the more restricted area, the more accurate it has to be. Most illustrated floras for beginners do not describe over 200 or 250 species, the most common from a large geographic area. The disadvantage of such floras is that the beginner does not learn to distinguish close species and instead agglutinates them under a unique name. Only a very few books exist that teach him to segregate close genera and species. It is the aim of this book to be such a bridge between elementary floras and scientific monographs. That aim is attained by describing as many as 1500 species from the ecologically homogeneous northern portion of France. To remain a field tool, the 27 dichotomic keys exclusively use macroscopic characteristics, covering the higher Ascomycetes and the Basidiomycetes. All characteristics are also outlined. Drawings are made of the 240 species. Differing from the famous *Flore analytique des Champignons supérieurs* by Kühner and Romagnesi, this key book uses correct updated nomenclature of the fungi. Perhaps is it a challenge identifying 1500 species by macroscopic characteristics only, but the author clearly says that no certified identification can be secured by using these keys only. The microscope and the use of good monographs are then required, at the end of the bridge. In the last part of the book, he purposefully introduces the student to observation of microscopic characters of the fungi.

GUIDE TO LOW COST MUSHROOM CULTIVATION IN THE TROPICS, by QUIMIO, TRICITA H., viii+73 p., 30 col. pl., 15 x 23 cm, hardcover, 1986. Dept. of Plant Pathology, College of Agriculture, University of the Philippines, Los Banos College, Laguna, Philippines.

Utilization of low cost materials and locally available agricultural wastes by individuals and cottage industries in both rural and suburban settings for the cultivation of mushrooms is what Dr. Quimio explains in her book. She describes the three steps of mushroom cultivation as the mushroom mycelium bank, the spaw production and the carpophore production. The first step is of importance, she says: "a good mycelium culture is the nucleus of the mushroom cultivation and its maintenance alive, healthy and in a condition as close as possible to the original condition is the first critical stage in the success of the mushroom cultivation." The spawn quality depends only on the correctness of the procedures applied for asepsy, sterility, inoculation and incubation, if the strain is of quality. The carpophore production shall also depend on specific procedures for each species. *Volvariella volvacea*, the most popular mushroom of Southeastern Asia, is not strictly restricted to straw and can be cultivated outdoors or indoors. *Pleurotus* species are mostly cultivated indoors in plastic bags. The ear fungi *Auricula polytricha* and *A. auricula* and shiitake, *Lentinus edodes*, grow on logs or sawdust. After production, conservation and commercialization are rightly advised; otherwise the author suggests a savory cooking in eastern style.

IL VASTO MONDO DEI FUNGHI, distruttori e rigeneratori della materia, by ONORATO, V., 246 p., 28 col. pl., 115 fig., 16 x 24 cm, paperback, 1985. Edagricole, 31 Via Emilia Levante, 40139 Bologna, Italia. ISBN 88-206-2300-5. L 20.000.-

The world of fungi is immense and extends itself to air, water and soil, far beyond the visible. The illustration of all its aspects, mainly microscopic or of chemical nature, is the object of this introductory work written for the layman. Fungi from the air, water, soil, wood or living beings are shown in their activities of biodegradation and biosynthesis, association, symbiosis and parasitism, and in their utility or noxiousness in respect to man. The text is clear and easy, ornamented with numerous illustrations, some of artistic fantasy.

I FUNGHI FRESCHI, SECCHI E CONSERVATI NELLA PRATICA ISPETTIVA, by TOGNI, N. and F. FIANDRI, 279 p., col. ill., 16 x 24 cm, paperback, 1987. Edagricole, Calderini, 31 Via Emilia Levante, 40139 Bologna, Italia. ISBN 88-206-2961-5. L 28.000.-

Les champignons sont d'une importance alimentaire croissante. Les chasseurs de champignons sont de plus en plus nombreux. Aussi ce livre veut-il, au-delà de sa partie introductive à la mycologie, fournir une mise en garde du public contre les intoxications par erreur d'identification ou par ignorance des propriétés de comestibilité des espèces. Pour ce faire, il décrit les syndrômes d'empoisonnement par les différentes espèces vénéneuses et toxiques et les premiers soins à prendre. De plus les auteurs veulent former le débutant à l'observation correcte des caractères diagnostiques des genres et des espèces, centrant l'attention sur les confusions possibles si souvent fatales. Ils le poussent jusqu'à l'usage du microscope et la mesure des spores. Par ailleurs un chapitre particulier attire l'attention sur l'absorption préférentielle par les champignons des métaux lourds, polluant l'environnement. Un aspect enfin que n'oublient pas les auteurs est le contrôle sanitaire et d'identité des champignons conservés et commercialisés et la réglementation en vigueur à ce sujet. Ce livre sera utile aussi aux médecins et pharmaciens.

FICHAS TECNICAS IVa SERIE, cards 73-122 , 17 x 21 cm, paperback, 1986. *FICHAS TECNICAS Va SERIE, cards 123-163,* 17 x 21 cm, paperback, 1987. Societat Catalana de Micologia, Facultat de Farmacia, Catedra de Botanica, Universitat de Barcelona, Av. Diagonal 643, 08028 Barcelona, Espanya.

These two new series including 90 descriptive sheets of fungi are prepared by mycologists of the Catalan Society of Mycologia. The contents consist of Latin names and synonyms, descriptive macroscopic and microscopic charateristics, habitat, collections and accurate line drawings of carpophores, cystidia, basidia and basidiospores. The author citations of names in the older series have not been amended in agreement with the present Code of Nomenclature, but well in the recent one.

BOLETS DE CATALUNYA, V Colleccio, plates 201-250, *BOLETS DE CATALUNYA, VI Colleccio*, plates 251-300, 17 x 21 cm. Edit. by Societat Catalana de Micologia, Facultat de Farmacia, Catedra de Botanica, Universitat de Barcelona, Av. Diagonal 643, 08028 Barcelona, Espanya. ISSN 0212-3460.

Two new sets each including fifty 20x13 cm color photographs of fungi, Myxomycetes, Ascomycetes and Basidiomycetes, are offered printed on the back side with the Latin name and a description of the illustrated specimen and its origin in both Catalan and Castillan languages. Although the fungi are often not photographed in their original position and habitat, the sets give an overview of a large range of species, including noteworthy uncommon fungi. To cite some of them, *Ceratiomyxa fruticulosa* var. *porioides, Ascocoryne cylichnium, Auriculariopsis ampla, Clavulina rugosa, Endoptychium agaricoides, Delastria rosea.* No doubt these records are a valuable contribution to the Spanish fungus flora.

THE NEW SAVORY WILD MUSHROOM, by McKENNY, Margaret and D.E. STUNTZ, revised by J.F. AMMIRATI, 264 p., 200 col. ph., 14 x 22 cm, paperback, 1987. University of Washington Press, P.O. Box C-50096, Seattle, Washington 98145-0096, U.S.A. ISBN 0-295-96491-X (cloth) -4 (Pbk). US $12.50.-

In this completely revised and enlarged edition, Joseph F. Ammirati, student and colleague of late Dr. Stuntz, adds new descriptions of genera and species and provides new and excellent 10x7.5 cm colour photographs for all of the 200 species described.The species are named by Latin binomials. They represent common mushrooms, edible or not, in the Pacific Northwest region of United States. A newly revised chapter by Dr. V.E. Tyler, of the School of Pharmacal Sciences at Purdue University, delivers the most up-to-date scientific information on mushroom toxins and poisonning.

MUSHROOMS, by McKNIGHT, K.H. and VERA B. McKNIGHT, Peterson Field Guides, xii+429 p., 48 pl., 12 x 19 cm, cloth hardcover, 1987. Houghton Mifflin Company, 2 Park St., Boston 02108, U.S.A. ISBN 0-395-42101-2. US $19.95.-

This pocket size field guide is a fine one, allowing recognition of 508 species amongst 1000 species considered for comparison. Those species are thoroughly described in almost 330 pages and are illustrated in 48 plates arranged in the middle of the book. Most of these illustrations are excellent accurate water-colour paintings on white background by Vera McKnight, resembling the style of the well known Jakob and Morten Lange's field guide. Other illustrations are fine pencil drawings. Full descriptions include

Latin name - which unfortunately does not appear on the plates -, macroscopic and microscopic features, comments on similar species and on habitat, odor, comestibility and taste. There are no keys, but fungi are arranged according to their outlook as defined in the introduction and mostly corresponding to taxonomic categories. Another feature of this guide is the attention to the variation of species depending on age and environment and the use of italics in the text and arrows on the plates to pinpoint the key characters.

CHAMPIGNONS, by BECKER, G., 319 p., ill., 256 col. pl., 22 x 30 cm, cloth, hardcover,1986. Gründ, Rue Mazarine 60, 75006 Paris, France. ISBN 2-7000-1516-9. FF 54.50.-

Georges Becker, author of many other French books on fungi, presents in this luxuous album water-colour paintings by Bohumil Vancura and descriptions of 255 species, mostly Basidiomycetes but 10 Ascomycetes. The mushrooms are carefully painted on a background of elements of their substrate or habitat. They are assorted with precise line drawings of their spores. The text is accessible and easy for anyone. On the contrary of many mushroom guides for beginners, this album illustrates many uncommon fungi of Western Europe that surely will spur the interest of mycologists. It is a fine mycological book that one shall love to have on the home bookshelf.

POISONOUS MUSHROOMS OF THE NORTHERN UNITED STATES AND CANADA, by AMMIRATI, J.F., J.A. TRAQUAIR and P.A. HORGEN, 396 p., 234 fig. (99 col. pl.), 22 x 28 cm, cloth, 1985. University of Minnesota Press, 2037 University Ave S.E., Minneapolis 55414, U.S.A. ISBN 0-8166-1407-5. US $75.-

Careless identification and indiscriminate tasting can result in poisoning. The mushroom hunter may not escape the event. Physicians, apothecaries, chemists, biologists, even mycologists, all face the task of identifying the implicated mushroom or debris of it. This book is designed to help accurate and quick identification of poisonous higher fungi of Northern North America. The first part is introductive to fungi, methods of study and classification with a key to genera and species. The main part deals with the seven distinct types of poisoning characterized by one major fungal poison present in a number of species. With deadly amatoxins, 32 species are described in *Amanita, Conocybe, Cortinarius, Galerina, Lepiota* and *Naematoloma*. Technical description with colour plates, habitat, distribution, seasonal occurrence and comments on toxicity, symptomatology and on poisonning cases are given for each taxon within each type of toxin. Monomethylhydrazin, the *Gyromitra* toxin, is found in 10 species, coprin in 4 species of *Coprinus* and *Clitocybe*, muscarin in 30 species of *Amanita, Boletus, Hebeloma, Inocybe, Clitocybe, Hygrophoropsis, Mycena, Omphalotus* and *Russula*, ibotenic acid and muscinol in 6 species of *Amanita*, the hallucinogens in 26 species of *Conocybe, Panaeolus, Gymnopilus, Pluteus, Psilocybe, Stropharia* and the gastrointestinal irritants, the most common, in more than 83 species within 30 genera.

GIFTPILZE, Ein Handbuch für Apotheker, Ärtze und Biologen, by BRESINSKY, A. and H. BESL, xii+295 p., 24 x 27 cm, 96 col. pl., 113 fig., cloth hardcover, 1985. Wissenschaftliche Verlagsgesellschaft, Postfach 40, D-7000 Stuttgart 1, Germany. ISBN 3-8047-0680-0. DM 136.-

This luxuous large sized book is all together a scientific work and a quality pictorial atlas of poisonous fungi from Central Europe. Knowledge on poisonous fungi is multidisciplinary and calls for chemistry, pharmacology, toxicology and medicine. But, at the basis, it requires a serious acquaintance with fungal taxonomy and identification. This book is however not arranged like a taxonomic flora. Aiming help to medical practitioners or biologists to recognize poisonous species, these are disposed according to their poisoning syndromes. Eight syndromes are defined and called phalloides, orellanus, gyromitra, muscarin, pantherina, psylocybin, coprinus and gastrointestinal syndroms. In each of them one or more species are described and illustrated. Similarities with other taxa and diagnostic difficulties are commented upon. Toxins are chemically defined and characterized. Poisoning cases are documented. Beside those syndromes, poisoning by uncooked mushrooms is considered. Fundamental differences exist, as stated in the introduction, between those syndromes and mycoses, mycotoxicoses, allergies, intoxications by heavy metals. The text is elaborated from the authors' research results and from 837 references to literature. It is to be appreciated as a full review of the subject.

AN ANNOTATED INDEX TO THE MYCOLOGICAL WRITINGS OF FRANZ PETRAK, Vol. 2, 3, 4, 5, compiled by SAMUELS, G.J., New Zealand Dept. of Scientific and Industrial Research Bulletin 230, 353 p., 445 p., 417 p., 535 p., 15 x 21 cm, paperback, 1982, 1983, 1985, 1986. DSIR, Science Information Publishing Centre, P.O. Box 8741, Wellington, New Zealand.

These are parts 2 to 5 of the voluminous index of the fungus names used or created by Franz Petrak in his mycological writings. Names are disposed alphabetically, with reference to Petrak's writings. Annotations are compiled that originated from literature about Petrak's taxa. These annotations concern anamorph-teleomorph connections, sources of information, or relationship to other taxa. Excicati of the taxon with references and hosts and substrate are also mentioned. All specific epithets with their generic name in parentheses are indexed. These indexes are cumulative and appear anew in each volume.

THE LACHNOCLADIACEAE AND CONIOPHORACEAE OF NORTH EUROPE, by HALLENBERG, N. and J. ERIKSSON, 96 p., 63 fig., 15 x 22 cm, 1985. Fungiflora, P.O. Box 95, Blindern, N-0313 Oslo 3, Norway. NOK 80.-

This volume is a complement to *Corticiaceae of North Europe* and comprises descriptions of species which belong to the corticioid fungi. The family Lachnocladiaceae is characterized by the presence of skeletal or binding hyphae with dextrinoid or cyanophilous walls. Four genera are included. *Asterostroma* is a noticeable one for its stellate branched setae and for its occurrence in domestic buildings. Coniophoraceae are characterized mainly by their brown cyanophilous spores with germ pore. Three genera are considered with four species in *Coniophora*, two in *Serpula* and two in *Leucogyrophana*.. *Coniophora puteana* is an important fabric wood-destroyer. *Serpula lacrymans* and *Serpula himantioides* also occur in buildings. They are very close species and difficult to distinguish. The authors indicate the non-cyanophilous and narrower skeletal hyphae, the non-gelatinized hyphae under the subhymenium, the thinner fruitbodies and the wider spores in the latter species and its adaptation to a much higher substrate moisture. This work is an important addition to the Corticiaceae of Europe and also will draw the attention of people in building survey and wood protection.

NORTH AMERICAN POLYPORES, Volume 1. Abortiporus-Lindtneria, by GILBERTSON, R.L. and L. RYVARDEN, 437 p., 209 fig., 16 x 23 cm, half calf, 1986. *Volume 2. Megasporoporia-Wrightoporia,* by GILBERTSON, R.L. and L. RYVARDEN, 437-485 p., ill., 16 x 23 cm, half calf, 1987. Fungiflora, P.O. Box 95, Blindern, N-0313 Oslo 3, Norway.

After *The Polyporaceae of North Europe* and *A preliminary Polypore Flora of East Africa*, L. Ryvarden assumes another task with R.L. Gilbertson, his North American colleague in the study of the Polyporaceae, to revise the North American polypores.Two volumes result from long years of collaborative work in the reexamination of type material from numerous American and European herbaria. With the concise style, precise terminology and high drawing standards that we already know in Ryvarden's publications, the authors redescribe almost all known species of polypores (in a broad sense) of North America. After the classical Friesian conspectus of the group by L.O. Overholts and its amendements made by J.L Lowe, and because of the extendsive use of new valuable taxonomic criteria such as hyphal types, sexuality, chemical reactions, type of rot and cultural characteristics, a taxonomic and nomenclatural revision was needed.

The authors do not pretend to offer a system of the polypores but merely a revision of poroid genera and species disposed alphabetically. One hundred genera are revised, sixty-four of them in the Polyporaceae, six in the Corticiaceae and the others from eight other families. The genera *Antrodia, Fomitopsis, Inonotus, Oligoporus, Perennipora, Polyporus, Trametes* and *Tyromyces* are described with ten or more species. A total of 399 species are described and their microscopic features illustrated. Addition of photographic or outlined illustrations of carpophores might have been valuable for the beginner. Species in genera and genera themselves are keyed out dichotomously. A synoptic key based on twelve major criteria is provided for genera; similar keys to species are also given in large genera. Easy to use, this book should enhance greatly the study of the polypore flora in America.

COMMON MUSHROOMS OF MALAWI, by MORRIS, B., 108 p., 8 col. pl., 15 x 22 cm, paperback, 1987. Fungiflora, P.O. Box 95, Blindern, N 0313 Oslo 3, Norway. NOK 130.-

African people have given proper names in their own language to many mushrooms for a long time. Mycologists are repeating the task but in a unique Latin language typifying the names for stabilization of the nomenclature. Collecting and identifying Basidiomycetes in Malawi (Africa), the author has taken notice of the African names and uses of the mushrooms. Of the 77 recorded species , thirty-three are currently eaten by people either as food or as condiment. The most appreciated are five species of *Cantharellus* and six of *Termitomyces*, but also *Amanita hemibapha, A. zambiana, Cymatoderma dendriticum, Lactarius vellereus, Russula atropurpurea* and *Suillus granulatus*. The descriptions of the taxa are very short . Twenty-eight taxa are illustrated in color plates.

ANNUAL REPORTS OF THE STATE BOTANIST 1868-1912, by PECK, C.H., *Vol. 1 (1868-1877)* , ill., 1980, *Vol . 2 (1878-1890)*, 187 p., 4 pl., *Vol. 3 (1891-1899),* 868 p., ill., edited by L. Vogelenzang, 15 x 23 cm, cloth hardcover, 1985. Boerhaave Press, P.O. Box 1051, 2302 BB Leiden, The Netherlands. ISBN 90-70153-12-2. Dfl. 200.- (vol. 2), 250.- (vol. 3).

Charles Horton Peck (1833-1917), Botanist at the State Cabinet of Natural History of New York from 1867 to 1883 and State Botanist of New York from 1883 to 1915 at the State Museum of Natural History in Albany, N.Y., was reporting yearly on his botanical activities at the Museum. In 1869 he published his first report (in the 22nd of the Museum) and he wrote 66 such reports up to 1912. In those, he set down his identifications and descriptions of plants and of all kinds of fungi from material collected by contributors or by himself. Very soon he contributed largely to the existing knowledge of the North American Agaricales and Boletales. The reports consist mainly in lists of identified plant and fungus material deposited in the Museum Herbarium and series of short descriptions of taxa not reported before amongst which many new species of Deuteromycetes, Ascomycetes and Basidiomycetes are named and described. Very early, Peck included in his reports monographic revisions on Basidiomycete genera, with keys, redescriptions and comments. These monographs were illustrated with engraved plates of drawings at first and with colour plates from 1894, sometimes with many of them like the 43 color plates of the 1894 report. These plates are reprinted in black and white in the present edition.

Working on the grounds of Schweinitz and in collaboration with M.C. Cooke and J.B. Ellis, Peck made one of the major contribution of his time to the North American fungus flora. The Boerhaave reprint of the reports is thus most welcome.

H.C.I.O. DESCRIPTIONS OF PLANT PATHOGENIC FUNGI, 1-6, maps, 23 x 29 cm, loose leaflets, 1986. H.C.I.O. Herbarium Cryptogamae Indiae Orientalis, Div. of Mycology and Plant Pathology, Indian Agricultural Research Institute, New Delhi 110 012, India.

This new series is closely similar to the *CMI Descriptions of Pathogenic Fungi and Bacteria*. Format, illustration and text style and contents are almost the same. It aims to document plant pathogenic fungi from India, provides their correct name, nomenclature, description, hosts disposed in plant families and alphabetically with localities, geographical distribution reported on a map of India and references to pertinent Indian literature. Each document consists of four printed pages. Each set shall contain six documents. The first one deals with *Erysiphe* species. The nomenclature is unfortunately out of date, not taking into account, in author citations, new article 13.1 and recomendation 50.E in the actual International Code of Botanical Nomenclature (Sydney Code, 1983), about starting point date and sanctioned status of names of fungi.

BRITISH FUNGUS FLORA, 4. Agarics and Boleti: Pluteaceae: Pluteus & Volvariella, by ORTON, P.D., 99 p., 78 fig., 15 x 24 cm, paperback, 1986. Royal Botanic Garden, Inverleith Row, Edinburgh EH3 5LR, UK. £ 8.-

Part 4 of the *British Fungus Flora* deals with two genera of the Agaricales with pink colored spores, *Pluteus* and *Volvariella.* The 43 British species of *Pluteus* are disposed in 3 infrageneric sections and 17 stirpes. In *Volvariella*, 11 species disposed in 6 stirpes are recorded. As in previous parts of the Flora, descriptions consist of macroscopical, microscopical and ecological data followed by comments and line drawing. Dichotomous keys to the species are provided in both genera . Four species that are not recorded in Great Britain yet are included however in the key. Indeed some species in *Pluteus* do not differ greatly from each other. This is why long, emphasized descriptive characteristics are used in constructing the keys. A list of species according their substrate, index of the described taxa and of rejected names, index of synonyms and misidentifications and index of specific epithets are added. For the attention of mushrooms growers, a list of references to the literature on the cultivation and the development of fruitbodies of those fungi ends the publication.

AN ANNOTATED INDEX TO SPECIES AND INFRASPECIFIC TAXA OF AGARICALES AND BOLETALES DESCRIBED BY WILLIAM A. MURRILL, by HALLING, R.E., Memoirs of the New York Botanical Garden, Vol. 40, 125 p., 17 x 25 cm, paperback, 1986. New York Botanical Garden, Scientific Publications Dept., Bronx, NY 10458, U.S.A. ISBN 0-89327-306-6. US $21.70 (U.S.A.), US $22.85 (elsewhere).

An important archival work has been necessary to orderly compile the information included in the index on species and infraspecific taxa described and on types or specimens collected by William A. Murrill. Murrill (1869-1975) was assistant then curator of the New York Botanical Garden from 1904, to which he added lots of collections in the Hymenomycetes including Boletales. Following the American Code of Nomenclature, he brought a number of new names and new combinations into the classical Saccardoan system.The author of the index compiled all names used or created by Murrill. Each name is listed with its reference, type locality, type material, authentic and other material, location in herbarium with numbers, nomenclatural and taxonomic comments with references. Most of the names created by Murrill proved to be superfluous according the Sydney Code and are marked by asterisk. This index is a new tool useful to the taxonomy and nomenclature of the Agaricales and Boletales.

10 JAHRE ARBEITSGEMEINSCHAFT MYKOLOGIE OSTWUERTTEMBERG (AMO), Beiträge zur Kenntnis der Pilze Mitteleuropas: Band 1: 1-208, fig., col. pl., 17 x 24 cm, paperback, 1984. Band 2: 1-240, fig., col. pl., 17 x 24 cm, paperback, 1986. Einhorn-Verlag, Eduard Dietenberger, Postfach 1280, 7070 Schwäbisch Gmund, Germany.

This publication celebrates the tenth anniversary of the Workgroup Mycology in the Ostwürttemberg, Germany, a section of the Deutschen Gesellschaft für Mykologie together with a group of mycologists of the Naturkundervereins of Schwäbisch Gmünd. There are two parts consisting of 20 scientific papers each. In part I, papers deals with *Lachnellula, Lamproderma, Lepidoderma, Kotlabaea, Trichophaea, Pycnopeziza, Cyathicula, Catinella, Coprinus, Cyphellostereum, Psathyrella, Pluteus, Psilocybe, Leucogyrophana, Phanerochaete, Clitocybe, Entoloma, Uredinales*. Part 2 deals with *Pyrenomycetes, Heyderia, Melastiza, Macrolepiota, Volvariella, Agaricus, Russula, Picoa, Psilocybe, Amanita, Lepista, Stropharia.*

SYSTEMA ASCOMYCETUM, by ERIKSSON, O. and D.L. HAWKSWORTH. Vol. 5, part 1, 184 p., 15 x 24 cm, paperback, 1986Vol. 5, part 2, 139 p., 15 x 24 cm, paperback, 1986Vol. 6, part 1, 200 p., 15 x 24 cm, paperback, 1987.Institute of Ecological Botany, University of Umea, S-901-87 Umea, Sweden or CAB International, Farnham House, Farnham Royal, Slough SL2 3BN, UK

Systema Ascomycetum is a serial publication now, published twice a year from 1986. The publication is not a mere alphabetical list of generic names proposed for Ascomycetes with mention of their synonyms and taxonomic position. The list is actually followed by "Notes on Ascomycetes systematics. N° 1-224" wherein the 224 first listed names are commented upon (Sept. 1986 issue). The comments deal with the taxonomic position of the taxon, its diagnosis, its typification, its circumscription, with reference to published literature or personal opinions. In July 1987 issue, notes on names n° 225 to 463 are offered. Furthermore, three papers on Ascomycete genera are contributed by J.R. Boise on *Mycopepon*, by P.F. Cannon on *Spirogramma* and by E.B. Gareth Jones and S.T. Moss on the Halosphaeriaceae.

From that issue, notes or short papers pertinent to the objectives of *Systema Ascomycetum,* i.e. revision of taxonomy and nomenclature of Ascomycete genera, are invited from all mycologists for inclusion. This serial publication is becoming a journal that all mycologists will welcome, appreciate and support.

FARBATLAS DER BASIDIOMYCETEN, by MOSER, M. and W. JUELICH, col. pl. and leaflets in portfolio, 22 x 26 cm, Set 1-2, viii + 88 pp., 152 col. pl., 1985; Set 3, 3O pp., 55 col. pl., 1986; Set 4, 30 pp.56 col.pl., 1987. Gustav Fischer Verlag, Postfach 720143, D-7000 Stuttgart 70, Germany. DM 394.- (sets 1-4).

These are the four first sets of a collection of loose cards held in a portfolio intended to be completed in 12 sets and covering 3000 species of fungi. The collection is divided into seven groups: Polyporales, Boletales, Agaricales, Russulales, Aphyllophorales, Heterobasidiomycetes and Gasteromycetes.

Each card is made of colour photographs of one or two species from the same genus. Cards are to be classified in the groups and within the alphabetical order of generic names. Printed sheets are delimiters between genera and bear information on nomenclature, type species, diagnosis, habitat and literature and are printed in German, English, French and Italian. The first sets 1 and 2 include 56 genera and 253 species, among which 54 are in *Inocybe,* 76 in *Lactarius*. Set 3 contains 7 genera, set 4 17 genera representing together 221 species, 75 of which are *Cortinarius* species. In each new set is an updated list of the included genera and species. The photographs are of excellent quality and of different styles. A few reveal the natural site. Most are photographed under light in the laboratory, some others show the fungus on a light blue cleaned background. Most reproduce natural colors very closely.

The true value of the complete work can be guessed at from the scientific reliability of the authors, the high quality of the illustrations, and its international scope. It seems destined to become a European reference flora for the higher fungi.

DIE GATTUNG RUSSULA IN BAYERN, by EINHELLINGER, A., Hoppea, Band 43, 348 p., 32 col. pl. , 15 x 21 cm, paperback, 1985. Verlag der Regensburgischen Botanischen Gesellschaft, c/o Universitätsbibliothek, Postfach 409, D-8400 Regensburg, Germany. ISSN 0340-4196.

This contribution to the fungus flora of Bavaria covers 153 species and varieties of *Russula* collected over seven autumns. Many of the species and varieties have not yet been recorded or identified in Bavaria. The taxa are described and discussed critically, with reference to J. Schäffer's and H. Romagnesi's monographs of *Russula*. Morphological data include careful spore diameter measurements, with the exclusion of the warts, unlike Romagnesi's spore measurements that include warts. Furthermore spore volume has been calculated with the statistical formula 0.53.L.W cubic microns. This value appears to be a criterion in the synonymy of *R. gigasperma* to *R. adulterina*. A long dichotomous key ends the work. The nomenclatural author citations are not consistently provided nor updated in accordance with the Code. Similarly to Romagnesi's monograph, there is no use of nomenclatural references nor publication dates. Many taxa are designated by names as interpreted (or misapplied) by authors ("sensu"). The regular misuse of ":" indicates a misunderstanding of the rules of nomenclature. Abbreviation "inkl. var." is used as, supposedly, to indicate the non acceptance of the variety, instead of formally listing the variety as synonym. Also varieties are synonymized in the text without being listed in the nomenclator. Such a tremendous taxonomic work clearly deserved better nomenclature. To be noticed: a new variety *gilva* is created in *Russula fragilis* . Thirty eight species, varieties and forms are illustrated by truly vivid full page water-colour paintings by Mrs. H. Marxmuller.

CONSPECTUS FLORUM AGARICALIUM FUNGORUM (AGARICALES s.l.) LITHUANIAE, LATVIAE ET ESTONIAE (materies 1778-1984 annorum), by URBONAS, V., K. KALAMEES and V. LUKIN, 138 p., 15 x 22 cm, cloth hardcover, 1986. Institutum Botanicae Academiae Scientiarum Lithuaniae Sovieticae Soc. Rep., Vilnius "Mokslas", Tartu, Lithuania, SSR.

The first edition of this Index dates from 1974. This is a new edition, that includes 1449 species, 62 varieties and 12 forms of the Basidiomycetes in Lithuania. They are disposed in orders, families and genera . A list of 506 bibliographic references and an epithet index are added.

DEUTEROMYCOTINA DE CUBA. HYPHOMYCETES I, by CASTANEDA RUIZ, R.F. and G.R.W. ARNOLD, Revista del Jardin Botanico Nacional, 2(1): 67p., 21 x 27 cm, paperback, 1985 (reprint); *DEUTEROMYCOTINA DE CUBA. HYPHOMYCETES II,* by CASTANEDA RUIZ, R.F., Serie Taxonomica del INIFAT, 24 p., 14 fig., 21 x 27 cm, paperback, 1985. *III,* by CASTANEDA RUIZ, R.F., Serie Taxonomica del INIFAT, 102 p., 30 fig., 21 x 27 cm, paperback, 1985. *IV* by CASTANEDA RUIZ, R.F., Serie Taxonomica del INIFAT, 38 p., 19 fig., 21 x 27 cm, paperback, 1985. Instituto de Investigaciones Fundamentales en Agriculture "Alejandro de Humbolt", Academia de Ciencias de Cuba, Santiago de Las Vegas, Calle 2 esq. 1, Ciudad de la Habana, Cuba.

The first fascicle which is a reprint starts a serial publication devoted to taxonomy. The four first issues deal with Hyphomycetes from Cuba. It immediately appears that the authors initiated a very fruitful study. The species collected are numerous and noteworthy. Already , of the 88 Hyphomycetes recorded in these four issues, 43 species were proposed as new and needed the creation of four new genera. These genera are *Bisseomyces* (*B. havanensis*) with dictyoseptate conidia on long denticles, *Holubovanella* (*H. elegans*) with successive clusters of brown phialides, dedicated to Dr. Vera Holubova-Jechova, Czechoslovakia, *Inifatiella* (*I. nectandrae*) with fasciculate conidiophores bearing long multiseptate brown conidia , dedicated to INIFAT and *Kostermansindiopsis* (*K. theobromae*) with dictyoseptate conidia in acropetal chains on fasciculate conidiophores. Each new taxon is illustrated by large line drawings. Type material and other collections are deposited in Castaneda's herbarium at the INIFAT.

ICONES MYCOLOGICAE 75-92, by RAMMELOO, J., edit., 17 p. + 16 col. drawings + 2 pl. phot., leaflets in paperback map, 1985. *ICONES MYCOLOGICAE 93-110,* by RAMMELOO, J., edit., 39 p. + 13 col. drawings + 5 pl. phot., leaflets in paperback map, 1985. *ICONES MYCOLOGICAE 111-130,* by RAMMELOO, J., edit., 51 p. + 8 col. drawings + 12 pl. phot., leaflets in paperback map, 1986. Jardin Botanique de Belgique, Domaine de Bouchout, B-1860 Meise, Belgium.

The National Botanic Garden of Belgium has been publishing the *Icones mycologicae* serially since 1982. The first issue was devoted to the master work of Louis Imler, a Belgian specialist of *Russula*. Subsequent issues provided more paintings of Imler and others. The folder 75-92 contains plates prepared by A. De Haan. Folder 93-110 contains 10 more plates by L. Imler and 8 by J. Rammeloo. The next folder has 4 more plates by Imler, 9 by J. Rammeloo, and 3 by F. De Raeve.

De Haan's plates are of eight species of *Galerina*. These very small fungi are delicately painted, with a photographic plate of spores under the scanning microscope. The plates painted and drawn by Louis Imler in the next two folders represent *Amanita flavorubens, Boletellus russellii, Boletus frosti, Boletus pallidus, Suillus pictus, Xanthoconium affine, Xerocomus illudens, Leucocoprinus bresadolae, Gyrodon merulioides, Russula grisea, Russula nigricans* and *Amanita spissa*. On all Imler's plates, carpophores are richly coloured and spores and hyphal elements are outlined by ink and faintly coloured. A plate of *Geopora sumneriana* is contributed by Heineman. F. De Raeve has prepared three plates, *Agrocybe pusiola, Inocybe aeruginascens* and *Melanoleuca cinereifolia*. J. Rammeloo composed 3 plates of colour photographs of Agaricales and 15 photographic plates of the Myxomycetes in scanning microscopy.

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